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ARCHAEOLOGICAL AND HISTORICAL LITERATURE SEARCH
AND RESEARCH DESIGN

LAVA FLOW CONTROL STUDY
HILO, HAWAII

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LAVA FLOW CONTROL STUDY
HILO, HAWAI'I

by

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GLOSSARY
OF HAWAIIAN TERMS USED IN THIS REPORT

<i>ahupua'a</i>	Land division, usually extending from the uplands to the sea
<i>'amakihi</i>	A group of small Hawaiian honey creepers, <i>Loxops virens</i>
<i>'ama'u</i>	All species of an endemic genus of ferns (<i>Sadleria</i>), with trunk more or less evident
<i>awa</i>	Milkfish (<i>Chanos chanos</i>)
<i>'elepaio</i>	A species of bird native to the Hawaiian Islands (<i>Chasiempis sandwichensis</i>)
<i>hāpu'u</i>	An endemic tree fern (<i>Cibotium splendens</i>)
<i>hau</i>	A lowland tree (<i>Hibiscus tiliaceus</i>)
<i>heiau</i>	A formal religious structure in pre-contact Hawai'i
<i>'ie'ie</i>	An endemic woody, branching climber (<i>Freycinetia arborea</i>) growing luxuriantly in forests at altitudes of about 1,500 ft
<i>kīpuka</i>	Variation or change of form (<i>puka</i> , hole), such as an opening in a forest and especially a clear place or oasis within a lava bed where there may be vegetation
<i>koa</i>	The largest of native forest trees (<i>Acacia koa</i>)
<i>kukui</i>	Candlenut tree (<i>Aleurites moluccana</i>)
<i>kūla</i>	Dry, gently sloping lands with little rainfall and few perennial streams
<i>lei</i>	A garland or wreath of various materials
<i>makai</i>	Seaward direction
<i>māmaki</i>	Small native trees (<i>Pipturus</i> sp.)
<i>māmāne</i>	A native leguminous tree (<i>Sophora chrysophylla</i>), which thrives at high altitudes up to the tree line
<i>mamo</i>	Black Hawaiian honey creeper (<i>Drepanis pacifica</i>) with yellow feathers
<i>mauka</i>	Inland direction
<i>noni</i>	The Indian mulberry (<i>Morinda citrifolia</i>), a small tree or shrub in the coffee family

GLOSSARY (cont'd.)

- 'ōhelo A small native shrub (*Vaccinium reticulatum*) in the cranberry family
- 'ōhi'a A tree in upland Hawaiian forests, *Metrosideros collina*
- olonā A native shrub (*Touchardia latifolia*)
- 'ō'ō A black honey eater (*Acrulocercus nobilis*) with yellow feathers
in a tuft under each wing
- pia Polynesian arrowroot (*Tacca leontopetaloides*)
- 'ua'u Dark-rumped petrel (*Pterodroma phaeopygia sandwichensis*)
- wauke The paper mulberry (*Broussonetia papyrifera*), a small tree or shrub

INTRODUCTION AND SCOPE OF WORK

Under contract to the U.S. Army Engineer Division, Pacific Ocean, the Department of Anthropology, Bernice P. Bishop Museum, conducted an archaeological and historical literature search to define and evaluate potential cultural resources that would be affected by lava diversion alternatives now under consideration in the contracting agency's Lava Flow Control Study. The data presented in the following report will be used to assess the impact of emergency diversion schemes devised to protect the Hilo area (Island of Hawai'i) from lava flows and to meet requirements set by the National Historic Preservation Act and the Reservoir Salvage Act.

The study area, or that area which could be affected by either the actual construction of the diversion structures or the diverted lavas, is delineated by the Wailuku River on the north, by the Hilo-Puna coastline on the east, by a line from Cape Kumukahi to a point at 9,500 ft elevation on the south, and by a line from this point roughly to Pu'u 'Ō'Ō Ranch on the west (Fig. 1).

The following four tasks were determined by the contracting agency (Scope of Work dated 12 December 1978) and undertaken by the author:

1. Literature and Data Review. All published and unpublished archaeological reports, field notes, and reference sources stored in the Bernice P. Bishop Museum and the Hawaii State Historical Preservation Office were consulted for known archaeological sites and hypothesized site distribution patterns in the study area. Almost all records of identified historic-period structures came from the files of the Historic Preservation Office, and all published material providing historical background information was found in the Bishop Museum Library. In addition, maps depicting early and late historic landscape features were briefly reviewed at the Geography Department of the Hilo College, the Hawaii State Survey Office in Honolulu, and the Pacific Science Information Center, Bernice P. Bishop Museum. A complete list of sources used is included in the Bibliography.

2. Inventory of Identified Historic and Prehistoric Sites. To facilitate the preparation and subsequent use of this report, the large number of known sites in the study area has been listed in tabular form along with descriptions, evaluations, and other available information (bound separately). If enough data were available, site locations were plotted on the accompanying U.S.G.S. Quadrangle maps.
3. Predictive Evaluation of Unidentified Resources. Based on data gathered during the above review and inventory, five major zones have been defined within the study area to delineate and discuss prehistoric and historic land-use patterns and the consequent likelihood of undiscovered sites. Factors leading to uneven land-use within each zone are also addressed.
4. Research Design for Further Archaeological Work. A multi-staged, stratified sampling design is proposed based on an evaluation of regional sampling surveys conducted in the Continental United States. Stratification is by major land-use zones, vegetation, and substrate variations within these zones. A systematic interval transect method is recommended wherever intrazone variations are minimal and the likelihood of cultural resources is high.

ENVIRONMENTAL SETTING

The windward or eastern sides of Mauna Loa, Mauna Kea, and Kīlauea Volcanoes, three of the five volcanic mountains forming the Island of Hawai'i, merge within the study area (Fig. 2). The topographic backbone of this area is the very active NE rift zone of Mauna Loa, which has created a highly variable landscape of alternating lava-flow types and ages. Most of the surface is composed of pahoehoe flows interspersed with several elongated or isolated pockets of aa flow. Soils derived from accumulations of organic material mixed with lava fragments (i.e., histosol soils) form either a continuous layer over these flows or occur as scattered pockets upon the bedrock, depending on factors such as local rainfall and the age and surface texture of the substrate.

Exceptions to this are remnants of certain older flow series capped with deep deposits of weathered ash (andepths soil) in the vicinity of Hilo Bay. Another band of these ash-derived soils stretches from Kea'au to past Mountain View, Puna (Fig. 3).

Flows from the even more active E rift zone of Kīlauea have covered portions of Mauna Loa, forming the SE portion of the study area from Ha'ena to Cape Kumukahi in Puna (Fig. 2). As on Mauna Loa flows, organic soils predominate, with the ratio of soil to lava outcrop varying with substrate differences. The NW corner of the study area includes part of the SE slopes of Mauna Kea that have escaped inundation by Mauna Loa lavas. The substrate of this Humu'ula-Pu'u Ō'ō Ranch area includes members of the older Hāmākua and younger Laupāhoehoe Flow series, covered with deep ash deposits (MacDonald and Abbott 1970:291-295; Soil Conservation Service 1972:4-6).

Knapp (1975:144), in defining major vegetation zones for Hawai'i, divided the windward side of these mountains into three zones: the submontane rain forest ranging from sea level to 2,000 ft elevation, the montane rain forest zone between 2,000 ft and 5,000 ft, and the upper montane or subalpine zone from 5,000 ft to beyond the upper limit of the study area. The delineation of these zones primarily reflects climatic factors such as orographic rainfall (i.e., that which is derived from moist air rising over mountain masses) and elevationally determined temperature ranges. The substantial successional variations in vegetation type within each of these zones reflect the combined influence of age, rainfall, and substrate differences.

The submontane rainforest zone, corresponding to the coastal-lowland forest zone classification of Robyns and Lamb (1939:263), receives approximately 125 to 200 in. of annual rainfall. This rainfall is slightly higher in the N portion of this zone, declining to 50 in. in the SE portion of the study area. Where not presently disturbed by agricultural and urban use, the older forest types are characterized by mixed native and introduced lowland species (e.g., *Metrosideros collina*, *Pandanus odoratissimus*, *Aleurites moluccana*, *Psidium cattleianum*, *Melastoma malabathricum*). Polynesian and historically introduced species are heavily represented in these forests, as well as in dense shrub and herb formations typical of secondary forests (i.e., a forest regenerating after the total or severe disruption of the

original forest). On younger flows, particularly those of Kīlauea, lowland pioneer or early successional plant communities predominate (e.g., *Dicranopteris linearis*, *Andropogon virginicus*, *Arundina bambusifolia*, *Lycopodium cernuum*, *Sadleria cyatheoides*). The common assortment of windward strand species (e.g., *Scaevola taccada*, *Batis maritima*, *Fimbristylis cymosa*) appears on unaltered shorelines (Fosberg 1972:139; Knapp 1975:105).

Within the montane rainforest zone, mean annual rainfall decreases in two gradients--from N to S (i.e., from 250 in. along the Wailuku River to 150 in. near Stainback Highway) and from E to W with increasing elevation (i.e., from 200 in. at 2,000 ft elevation to 100 in. at 5,000 ft). 'Ōhi'a (*Metrosideros collina*) is the dominant tree species for most of this zone within the study area. Koa (*Acacia koa*) occurs as a codominant with 'Ōhi'a in two disjunct bands--one below 2,500 ft elevation and one above 5,000 ft on scattered, older substates. An atypical strip of koa-'Ōhi'a forest between 2,500 and 5,000 ft does occur along the Wailuku River, possibly in response to improved drainage along the banks.

Understory and ground-cover types directly reflect the degree of canopy and subcanopy cover of the dominant species. For example, an open canopy and subcanopy can be accompanied by a dense tangle of matted ferns (e.g., *Dicranopteris linearis*, *Stickelus owhyhensis*, *Hicriopteris pinnata*), open patches of wetland grasses and shrubs, and an obstacle-course jumble of fallen logs. A closed canopy and subcanopy shades an assortment of ferns (e.g., *Microlepia strigosa*, *Athyrium sandwichianum*, *Asplenium* spp.), shrubs (e.g., *Coprosma* spp., *Broussaisia arguta*, *Pelea clusiaefolia*), epiphytes (e.g., *Adenophorus* spp., *Grammitis tenella*, *Vandenboschia davallioides*), rambling mints (e.g., *Stenogyne calaminthoides*, *Phyllostegia vestita*, *P. villosa*), and herbs (e.g., *Peperomia* spp.) (Knapp 1975:100-101; Fosberg 1972:148-150; Mueller-Dombois 1977:101-116).

Rainfall decreases from 150 in. at 5,000 ft elevation to 30 in. at 9,500 ft in the montane and subalpine zones. The high percentage of historic or relatively recent flows on Mauna Loa, plus the effects of low rainfall and temperature, gives much of this zone a barren appearance. As a result, the vegetation varies from early pioneer moss and lichen communities through successional stages of scrub communities (e.g., *Styphelia tameiameia*, *Metrosideros collina*, *Vaccinium* spp.) and forest. There are

also areas of mountain parkland, a mixture of scattered canopy trees (*Metrosideros collina*, *Acacia koa* and *Sophora chrysophylla*) and associated native and introduced grasses, ferns, and shrubs (Knapp 1975:103; Robyns and Lamb 1939:263; Fosberg 1972:193).

REVIEW OF ARCHAEOLOGICAL LITERATURE

The earliest systematic records of archaeological sites within the study area are lists and descriptions of all known *heiau* on the Island of Hawai'i. Based on informant data, both Thrum's published, annotated list (Thrum 1907) and Stokes' (1919) unpublished manuscript discuss the type, religious function, condition, and historic or legendary background of each *heiau*. Stokes' more lengthy descriptions were based, in part, on field inspection. Thrum mentions no *heiau* for the area between Hilo, where most were already destroyed, and the area just S of the study area.

Between 1930 and 1932, Alfred E. Hudson undertook a site inventory and survey of the entire E coast of Hawai'i. Focusing mainly on the classification of site types based on form and assumed function, he identified 85 sites or site complexes between Hilo and Cape Kumukahi. The wide range of structural remains recognized includes the *heiau* mentioned above, platforms, shelter caves, fishing shrines, trails, and agricultural features. After reviewing previously known sites and several journals written in the early 1800s, Hudson walked the coastline, heading inland only if informed of a specific site.

From 1932 until about 1970, incidental descriptions of sites were made by Bishop Museum staff members and interested individuals. Notable examples are Kenneth Emory's explorations of "Shipman Cave" (Site 50-Ha-A1-1), Lloyd Soehren's investigations at Kahuwai Village, and Violet Hansen's numerous field trips. All records are stored as field notes and photos in the Department of Anthropology, Bishop Museum, and/or with the individuals. Russ Apple (1965), in discussing prehistoric and historic trail typology and use, noted the presence of prehistoric and historic trail types in Puna.

With the advent of "contract archaeology" in Hawai'i and an increased emphasis on including cultural resources in the processes of planning and development, numerous reconnaissance surveys were undertaken in the Hilo and Puna Districts. Apparent in the resulting reports is the trend toward settlement pattern archaeology, in which importance is placed on the distribution of all structural remains or landscape modifications as they apply to land-use patterns and population dynamics. In contrast, pre-1970s work tended to stress only certain types of sites, such as religious structures, burials,

and areas rich in lore or artifacts. Thus, the number of recognized and recorded sites (when not grouped in a complex) increased dramatically during the more recent surveys.

From 1970 to the present, most of these contracted surveys took place south of the study area. The reports of Crozier and Barrère (1971), Barrera and Barrère (1971), much of Bevacqua and Dye (1972), and Barrera (1973), describe site distributions and types close enough to the study area to merit some comparisons. Rapid change in climatic factors, substrate patterns and estimates of higher population densities in prehistoric time within the southern half of Puna (Hudson 1952:337-338), make comparisons with the study area less valid.

The Bishop Museum conducted the most extensive walk-through survey within the study area's boundaries, following a proposed highway corridor from Kalapana, Puna, to Keaukaha, South Hilo (Bevacqua and Dye 1972; Ewart and Luscomb 1974). Only one section between the *ahupua'a* of Kula and Waiakahiula was not covered by the 2,000 ft-wide corridor, which closely followed the coastline with the exception of some *kula* sections. More limited surveys concentrated on portions of Kaūmana, above Hilo proper (Sinoto 1975 & 1978), and an area under intense sugar cultivation near Mountain View (Dye 1975).

The commissioning of cultural resource inventories by the Bishop Estate, the Department of Planning (County of Hawai'i), and the Department of Land and Natural Resources (State of Hawai'i) between 1970 and 1974 provides further evidence of government and private planning efforts. The County inventory, calling for field inspection and evaluation of known sites in North Hawai'i, evaluated only three sites within the study area (Loo and Bonk 1970). Bishop Estate's inventory involved only a literature review of sites known to be on their land, and only Kahuwai, Puna, falls within the realm of the present study area (Barrera 1974). In 1974 and 1975, the State of Hawai'i attempted to systematically and consistently record and evaluate all previously identified sites in the State, to establish a central storehouse of archaeological data for planners and archaeologists alike. Thus far, 13 archaeological sites have been processed for the study area.

An example of recent archaeological, non-contract work, is William Kikuchi's dissertation on Hawaiian aquaculture practices, which identifies

and classifies 21 ponds between Hilo and Puna (Kikuchi 1973). This does not represent an exhaustive inventory, however, as lack of funds limited his survey to accessible ponds.

A complex of probable prehistoric features on adjacent aa and ash substrates has been uncovered since 1974 by the staff at Honua Hawai'i, an outdoor educational center encompassing 202 acres on the edge of the Pana'ewa Forest Reserve. Features included agricultural terraces and mounds characteristic of wet and dry agriculture, trails, and a modified overhang. Reports and field notes written by several knowledgeable professionals and lay people are on file at the Honua Hawai'i office.

Even the combined results of all these reports, however, do not provide an adequate basis for predicting site distribution, although several factors that influence site distribution are suggested. Coverage of even the most extensively examined coastal area remains incomplete. For example, Hudson mentioned the presence of sites between Hā'ena and Maku'u, but failed to record any of them (Hudson 1932:60). Ewart and Luscomb (1974:11) followed the route of the proposed highway and were on occasion foiled by dense vegetation, making their results non-representative. Inventories have tended to reinforce the early bias toward certain site types, while the few areas inspected above the coastal area (all below 1,500 ft elevation) were selected on the basis of development and funding decisions--i.e., limited by "artificial" restrictions.

The relationship between substrate age and the distribution or densities of sites along the Puna Coast has been suggested, although without elaboration (Barrera 1973:3; Bevacqua and Dye 1972:24). Site concentrations plotted by Ewart and Luscomb tend to show a remarkably high correlation with the distribution of relatively deep organically derived soils, which are usually underlain by aa flows. As delineated by the Soil Conservation Service, these soil types are surrounded by younger flows with little or no soil development. These older flows also exhibit topographic features that are recognized as conducive to human settlement, such as more readily available ground water from wells or springs, and lower cliff formations with boulder and sand beaches on coasts otherwise characterized by sharp cliffs (Ewart & Luscomb 1974:47).

Disruption of sites due to urban and agricultural development is the most apparent limiting factor in determining site distribution in regions immediately inland from the coast. Dense underbrush, characteristic of the secondary forests below 1,500 ft elevation, prohibits the detection of sites and analysis of site distribution (Sinoto 1975:2, & 1978:3; Ewart & Luscomb 1974:11). Sinoto reported two possible agricultural features and an extensive complex in areas either unaltered or free from dense ground cover. Sinoto's findings and those at Honua Hawai'i are important as examples of site possibilities in areas that are often overlooked, and as evidence of the surviving representatives of former and possibly extensive complexes.

EXPLANATION OF SITE INVENTORY*

The format presented in the site inventory and many of the criteria used in summarizing site data essentially follow those presented by Rosendahl (1977:1-5). As with previous inventories, problems arise in consistently describing and evaluating structures not seen by the author and originally described by a variety of people over the last fifty years. This is particularly true when the large number of sites requires concise terminology to summarize frequently incomplete data.

Sites are grouped by *ahupua'a*, ordered as they occur from N to S. Within *ahupua'a*, sites are listed numerically by Bernice P. Bishop Museum Site Number or Hawai'i State Historic Preservation Office Number. Those sites, mostly trails, that extend over more than one *ahupua'a* appear at the end of the inventory.

Included under site descriptions are both the site's common name, if known, and the descriptive term indicating the site type and/or assumed function. Site names apply mostly to historic structures and prominent prehistoric sites that have commonly used local or historical names. With few exceptions, the site type assigned by the original recorder was used and no attempt was made to reclassify into a consistent typology. Fortunately, most original descriptions fell within the range of descriptive types commonly used in Hawaiian archaeology.

Two major time periods, prehistoric and historic, are commonly assigned to structural remains based on probable period of construction, occupation, and/or modification. Although these designations can only be verified by conclusive excavation results or historic records, field judgments are generally made on the basis of structural elements believed or known to be traditionally Hawaiian or, in the case of historic structures, of representative styles or construction methods. Often the presence or absence of prehistoric or historic artifacts and debris can be the deciding factor. Period assignments are included only if they were specifically mentioned in the original description or if the description is complete enough to merit interpretation.

The condition of a site is based on specific assessments made in the original or latest recorded description. Assessments made even as recently as six years ago, however, may not reflect the current condition, due to

*Site inventory is bound separately.

either natural or man-induced impact. The descriptive terms used (i.e., Excellent, Good, etc.) reflect the initial recorder's qualitative impression of the site's condition relative to its assumed original formation.

Two systems of significance potential have been used. One system, elaborated by Rosendahl (1977:1-15,16) and used for other Bishop Museum projects, applies to archaeological resources. The other, applying only to historic-period structures, was developed during the Statewide Inventory of Historic Places. Major criteria for judging the significance of archaeological resources are the potential for "yielding information important in local, regional, or extra-regional history or pre-history; and/or development as a public-use facility illustrating some aspects of cultural history, life-ways, or the cultural processes" (Rosendahl 1977:1-15); in other words, in terms of the research and/or interpretive possibilities of each resource. Research Potential (RES) implies preservation of the important data that could be derived from the study of a particular resource. "Poor structural condition, lack of uniqueness, or practical difficulties of interpretive presentation" (Ibid.:1-16) may make such a site inappropriate for interpretation purposes. "Interpretive Potential" (INT) implies preservation of a unique or good representative example of a site type conducive to public interest. "Interpretative and Research Potential" denotes the combined attributes of both categories. "Minimal Research and/or Interpretive Potential" implies that a site, either a common type or in a deteriorated condition, has little potential for supplying much important data, or is of little interest to the public. This last rating, however, does not preclude preservation, since a resource's potential may be reevaluated in light of future research or changes in public interest.

At present, the significance ratings used by the principal investigators during the Statewide Inventory of Historic Places are being reevaluated and replaced by a new set of criteria. As these new assessments are not available, the original determinations made during the Inventory have been used with the understanding that they do not reflect current State of Hawai'i policy. They do, however, serve as a guideline to the relative merits of each historic structure, based on such factors as architectural uniqueness, historical background, or representative style. Historic sites listed on the National or State Registers of Historic Places represent official evaluations similar to those applied by Rosendahl to archaeological sites.

HISTORICAL LITERATURE SEARCH

Historic and ethnographic literature was researched in the Bishop Museum library to form the basis for an analysis of early historic-period land use in the study area and vicinity. The journal accounts referred to below, written between 1779 and 1846, represent only a portion of the potential data available. These works were selected for their breadth of scope, the detail of their descriptions, and/or their depiction of different periods between initial European contact and the first of the several epidemics that so severely depopulated the area.

The earliest accounts are invaluable, as they depict cultural practices that had received little or no impact from Western influences and describe a landscape still unaltered by introduced feral ungulates (i.e., cattle, sheep, goats, etc.). The missionaries had the benefit of repeated and extended exposure to the area, while the accounts of the relatively brief visits of exploring parties provide details of the landscape in keeping with their purposes.

A complete list of all sources consulted is included in the Bibliography. The following summary provides a brief historical background of the major journals selected:

(1) John Ledyard and David Samwell sailed with Capt. Cook in 1779 along the eastern coast of Hawai'i and ventured into the forests above Kealekekua, Kona (Ledyard 1963; Beaglehole 1967).

(2) Archibald Menzies, the surgeon-naturalist, accompanied George Vancouver on his three visits to Hawai'i between 1792 and 1794. His observations of the study area were all made from offshore, as Vancouver was unable to find proper anchorage. Menzies did explore the inland regions of Ka'u and Kona and described practices that were probably analogous to those of the study area (Menzies 1920).

(3) William Ellis, an English missionary, toured the Island of Hawai'i in 1823 to assess potential locations for mission stations. His trek along the Puna coast to Hilo Bay generated the earliest overland description of the coastal zone (Ellis 1963).

(4) Joseph Goodrich, one of the first two American missionaries appointed to the Hilo Mission Station, resided there from 1824 to 1835 (Goodrich 1826, 1829).

(5) Andrew Bloxam (a naturalist), James Macrae (a botanist), and Charles Stewart (an American missionary) accompanied Lord Byron on his voyage to Hawai'i to return the bodies of Kamehameha II and his wife, who had died in London. Anchoring in Hilo Bay, all described the area around Hilo Bay, the South Hilo district, and the route through Ōla'a to the Volcano in 1825 (Bloxam 1925; Byron 1926; Macrae 1922; Stewart 1970).

(6) David Douglas, a Scottish botanist, spent several months in 1834 collecting specimens on the slopes of Mauna Kea and Mauna Loa (Douglas 1834, 1914).

(7) Titus Coan, appointed minister of the Hilo Mission in 1834, made repeated tours through the Puna and Hilo Districts as part of his regular duties (Coan 1882).

(8) During their worldwide tour from 1838 to 1842, the U.S. Exploring Expedition, under the command of Capt. Wilkes, anchored in Hilo Bay to collect a variety of data. Selections from Wilkes' own published narrative and the journals of Brackenridge (a botanist), Pickering (an ethnographer and naturalist), and Peale (a naturalist) provide many valuable details (Brackenridge 1840-41; Pickering 1841-41; Wilkes 1845).

(9) In 1846, Chester Lyman (a sometime professor of astronomy and physics at Yale) described his stay in Hilo and his overland trip through Puna in the company of Rev. Coan (Lyman 1924).

ZONES OF EARLY HISTORIC-PERIOD LAND USE

(See Fig. 4)

Analysis of the accounts listed above (pp. 12-13) indicates that five zones of Hawaiian settlement and land use--the coastal settlement, upland agricultural, lower forest, rainforest, and sub-alpine zones--existed during the early nineteenth century. Although the accounts were written during a period of enormous change and upheaval in Hawai'i, the repeated and consistent references to certain landscape features and cultural practices justify the proposed framework of these five zones and suggest that this pattern existed at the time of Western contact and possibly earlier.

While the limits of these five zones do correspond roughly to elevation, considerable variations occur within each zone due to the geological formations of the three volcanic masses underlying the study area. Hawaiian adaptation, if seen in terms of these formations, can be characterized by the two extremes of windward Mauna Kea and Kīlauea. Mauna Kea, best exemplified by the slopes between Hilo Bay and the district of Hāmākua, has a relatively uniform topography covered by thick ash deposits intermittently dissected by youthful valley and gulch formations caused by stream erosion (MacDonald & Abbott 1970:165). Likewise, the land-use patterns were uniform, consisting of more concentrated settlements on gulch or valley floors near the coast and of widely spaced plantations and huts scattered across an "unwooded," gentle slope up to 2,000 ft elevation (Ellis 1963:349; Macrae 1922:48-49; Menzies 1920:51). It has been suggested that the steep cliffs, the small number of protected bays, and the frequently rough ocean limited fishing opportunities, thus explaining the relatively low population of the area (Ellis 1963:351).

On Kīlauea, the surface is predominately composed of pahoehoe flows intersected by several strips of aa substrate. Recent geological studies suggest that the entire surface of Kīlauea, especially that within the study area, is less than 800 years old (Jack Lockwood, pers. comm.). This being well within the potential time span of Hawaiian settlement, adaptation patterns centered around maximizing use of a frequently changing landscape with a rough, uneven, and highly variable surface having little soil development. Practices typical of the area, such as the modification of

lava tubes and outcrops for shelter, the use of mounds and mulching for planting, and the correlation between substrate age and site densities (see page 8) typify this adaptation.

Mauna Loa, having flows representing a much longer time span, contains substrates conducive to both adaptive patterns. That is, flows underlying organically derived soils reflect the use patterns of Kilauea flows, while those capped with ash reflect Mauna Kea patterns. Within the arbitrary boundaries of the study area, only the coastal settlement and the upland agricultural zones are directly affected by these substantial differences in substrate and the resulting adaptive patterns.

Zone I Coastal Settlement

The highest numbers of people in the early historic period, and subsequently the highest site probabilities, are found in this zone from sea level to roughly 20 to 50 ft elevation or 1/2 mile inland. Early descriptions, as well as the distribution of known sites, suggest that structures representing both permanent and/or temporary use occur along the entire coast. When not occurring singularly or clustered in small, widely spaced groups, settlements appear to have been concentrated around Hilo Bay and in six villages along the Puna Coast to Cape Kumukahi. The occurrence of ash soils, as those found in Hilo, or the better developed organic soils important to crops, of potable fresh and brackish water, of local coastline formations amenable to sea exploitation, and of ponds or streams for aquaculture and/or marshland taro cultivation (*Colocasia esculenta*) appear to be the major factors associated with population concentrations. Villages tended to appear either as a compact unit or as an elongate complex paralleling the coastline, as reported along Hilo Bay and at Waiakahiula.

In 1823, Ellis estimated that 2,000 people lived in 400 houses or huts along Hilo Bay. Consistently, this village was described as a nearly continuous complex of native huts and garden plots interspersed with shady groves of trees, predominately breadfruit (*Artocarpus altilis*) and coconut (*Cocos nucifera*). Other than these residential complexes, canoe sheds, several *heiau*, and large complexes catering to chiefs and their retainers were mentioned. Gardens, outlined by windbreaks or small plantations of bananas (*Musa* hybrids), sugarcane (*Saccharum officinarum*), and *wauke* (*Broussonetia papyrifera*) were primarily planted with dryland taro, mixed with sweet potatoes (*Ipomoea batatas*) and minor vegetable crops. Other economically valuable trees, mostly Polynesian introductions (e.g., *Eugenia malaccensis*, *Pandanus odoratissimus*, *Thespesia populnea*, *Aleurites moluccana*) grew singularly or as components of these groves.

In addition to supplying fresh water, Waiākea pond, its outlet the Wailoa River, and the neighboring Waialama River were modified and maintained as fishponds. Use of the "Royal" Waiākea fishponds, although teeming with fish (*awa* and mullet), and occasionally ducks, was restricted to those of higher social ranking. The marshlands surrounding these ponds were planted in taro by a mulching and mounding method supposedly unique to the area. The Wailuku River played an important part in recreational, trading, and ritualistic practices, while the comparatively larger size of houses and the villagers' kingdom-wide fame as canoe builders were attributed to a more readily available supply of straight, tall timber. All these factors, plus the advantages of the largest, best protected bay along this portion of the coast for the exploitation of marine resources, helped to make Hilo the single most populated spot in the study area (Douglas 1914: 304; Byron 1825:165-168; Macrae 1922:46-47; Bloxam 1925:51-52; Ellis 1963:320-337; Menzies 1920:141; Wilkes 1845:114-117; Stewart 1970:362-367.

The rough, highly variable landscape created by both pahoehoe and aa flows of Kīlauea and Mauna Loa volcanoes stretches from Wailoa Stream to Cape Kumukahi. The selected literature evidences a total of six concentrated early historic settlements or villages along this stretch (Kea'au or Haena, Maku'u, Wai'akahiula, Honolulu, Kahuwai, and Kula or Koa'e). Each seems to have comprised the same complex of huts, gardens, windbreaking shrubs, and utilized groves, although the form and overall size of each appear to

differ. The major differences between this portion of the coast and Hilo occurred in the type of agriculture practiced and the structural forms reflecting the uneven nature of the young terrain. Platforms and walls were built to include and abut outcrops, crevices were filled and paved for burials, and the large numbers of loose surface stones were arranged into terraces. To supplement the limited and often spotty deposits of soil, mounds were built of gathered soil, mulch, sorted sizes of stones, and in many circumstances, ash from burnt brush surrounding the gardens. Although all the major cultigens appear to have been present in these gardens, sweet potatoes, ti (*Cordyline terminalis*), noni (*Morinda citrifolia*), and gourds (*Lagenaria siceraria*) seem to have been more conspicuous. Breadfruit, pandanus, and mountain apple (*Eugenia malaccensis*) were the more significant components of the groves that grew in more disjunct patterns than those adjacent to Hilo Bay.

Access to marine resources and fresh or brackish water probably played a major role in attracting concentrations of people, as well as influencing the location of isolated or small clusters of huts. As previously mentioned (see p. 8), the fact that densities increased along low cliff formations is reinforced by descriptions of mapped and identified canoe landings, the large number of fish brought out to supply foreign ships, the use of hand-nets for crabs, and the development of an elaborate, wooden lattice-framed structure to land canoes in rough waters along low cliffs. Most accounts mention the lack of readily available fresh water and discuss the presence of underground water in caves, the use of brackish water from coastal springs, and catchment schemes involving the use of ti leaves and calabashes to gather cave drips and rainfall. Aquaculture was also practiced in the scattered ponds along the coast, particularly those just SE of Hilo and at Haena, as well as marginal, marshland-type taro cultivation (Beaglehole 1967:1155-1156; Pickering 1840-41:177-185; Ellis 1963:297-305; Thrum 1909: 97-100; Hillebrand 1905:xxii; Lyman 1924:88-96).

Assuming that these six defined villages generally coincide with their locations on current U.S.G.S. maps, their distribution, like the higher site densities found by Ewart and Luscomb, basically coincides with the older aa and pahoe flows that have deeper, organically derived soils.

Of the seven villages, four (Haena, Wai'akahiula, Kahuwai, and Honolulu) are underlain by aa flows and two (Maku'u and Koa'e) by pahoehoe flows. Thus, in addition to the obvious advantages of more advanced soils on older flows, the previously mentioned association between older flows and lower cliff formations, and closeness to basal water lenses, aa flows appear to have been even more conducive than pahoehoe to human settlement because the more notable village complexes occurred on them.

This may be best explained in the study by Powers, Ripperton, and Goto (1932) of coffee cultivation in Kona, where substrates vary at least as much as they do in the study area. They found that this singularly planted crop did best in aa substrates with some organically derived soils within a uniform rainfall and temperature regime. This success was attributed to the capacity of aa to provide needed minerals by decomposing more rapidly, to retain water longer during dry periods while draining excess water more quickly, to pocket and accumulate organic debris, and to allow the penetration of roots more easily.* These characteristics would not only directly benefit the crops planted in mounds and crevices, and tree crops such as breadfruit, but would also speed up the initial establishment of the primary forest and therefore accelerate the accumulation of organic soils.

An excellent example of adaptation to this otherwise troublesome terrain is the raised trail (Site 50-Ha-A6-20) at Kahuwai.

Zone II Upland Agricultural Zone

Although estimates as to the extent of this zone vary in early journal accounts, most confirm an expanse of unwooded grasslands or a "plain" behind Hilo and in a band from Kea'au to roughly Mountain View, basically corresponding to the distribution of ash soils shown in Figure 3. Scattered huts, emphasized by adjacent garden plots and small groves of economically beneficial tree species, dotted this expanse up to 1,500 ft elevation (i.e., the edge of the forest). The cumulative effects of shifting agricultural practices (i.e., slash-and-burn or swidden), prevalent among Polynesian and Pacific peoples,

*Pahoehoe flows can have similar properties when the surface is exceedingly fractured.

probably created and maintained this open grassland mixed with pioneering species and species that tolerate light and regenerate after a fire. The effects of agricultural practices on the younger, non-ash substrates of Mauna Loa and Kīlauea is less clear, though descriptions of burning and planting within these areas do exist and imply the possibility of agricultural and residential remains. On the widely spread pahoehoe flows of Kīlauea that fall within Zone II, land-use may have focused on the extensive lava tube channels underlying the area. Within this zone, the possibilities of remnant agricultural complexes could be high on both ash and older aa or pahoehoe substrates that have not been disrupted by historic agricultural practices.

With remarkable consistency, early visitors to Hilo Bay describe an open parkland gently sloping to the base of the woods. This open but verdant expanse, broken by widely spaced "cottages" or huts, neatly tended gardens, and small clusters of trees, was comfortingly reminiscent of English or New England countrysides. Estimates as to the extent of this unwooded expanse ranged from between five and six miles (Goodrich 1826:4) to between three and four miles (Coan 1882:29) above the coast or village, with most falling between four or five miles. Both Douglas and Pickering set the upper limit of this zone at 1,500 ft elevation, which currently appears on the U.S.G.S. maps as five miles from the shoreline along the general route followed by both writers on their way to Mauna Kea (Pickering 1840-41:148; Douglas 1834:333).

The constituents of gardens and tree crops in the village basically continued in the upland except that dry-land taro was planted more extensively and bananas were more numerous. Wet or irrigated taro occurred along small streams, tributaries, and rivers that cut into the ash-capped substrates. In 1825, on a similar substrate in the N Hilo District, huts and cultivated fields decreased with increasing elevation (Macrae 1922:49). Whether Menzies' description of "neatly laid out fields" (Menzies 1920:51) in this same area implies the existence of field boundaries on these windward slopes, similar to those found in the leeward agricultural fields, is difficult to discern (Douglas 1834:333-334, 1914:298-304; Pickering 1840-41:6; Stewart 1970:361; Goodrich 1826:4; Ellis 1963:-37; Bloxam 1925:51).

This same pattern occurred between Waiākea Pond and the Pana'ewa Forest in the four or five miles of open country dominated by tall grasses. Here

stands of *kukui* (*Aleurites moluccana*), pandanus, and mountain apple became more conspicuous, with large areas of dryland taro planted in rocky crevices on the younger Mauna Loa flows. The 4-mile-wide forest, corresponding to the present Pana'ewa Forest Reserve, grows on a single flow roughly 2,700 years old (Jack Lockwood, pers. comm.) and in the early 1800s was one of the few forests to nearly reach the ocean. The trail leading from Hilo to the Volcano through this dense stand of 'ōhi'a ferns, and 'ie'ie (*Freycinetia aborea*) again comes upon an unwooded landscape near what is now Kea'au.

The Volcano Trail then crossed two deducible substrate types between Kea'au and what is now called Mountain View (also the southern limit of the study area). The first portion was described as more unwooded country showing signs of cultivation and extended three and a half to five miles, to the vicinity of Kurtistown. Situated on a mosaic of mostly ash-capped flows with patches of aa and pahoehoe flows overlain with shallow, organically derived soils, the ground cover was dominated by ferns, grasses, shrubs, and *pia* (*Tacca leontopetaloides*), interrupted by abundant stands of *hau* (*Hibiscus tiliaceus*), *ti*, pandanus, and breadfruit. From here to Mountain View or just beyond the "halfway house," the trail crossed onto an extensive Kīlauea pahoehoe flow and continued along its western margin, which abutted mostly ash-covered Mauna Loa flows. The route of this old trail basically corresponds to the Ōla'a-Kea'au boundary line on current U.S.G.S. maps. Descriptions of scattered, stunted trees, mixed with ferns, grasses, 'ōhelo (*Vaccinium* sp.), and low shrubs, sound typical of pioneer or early successional plant communities. When compared to the previous portion of the trail, ferns became more dominant, *pia* disappeared, and scattered clumps of woods, probably small *kīpūkas*, replaced the groves.

On both portions of the trail, the woods started one or two miles SE and NW of the path, giving it the appearance of an unwooded corridor. Several villages, as well as scattered huts along the forest edge, were reported without much detail other than the presence of fertile soil and a burial cave marked with poles. Most describe leaving this open stretch somewhere beyond the "halfway house" by entering a thick forest, which Pickering placed at 1,500 ft elevation (Pickering 1840-41: 7; Bloxam 1925:54-62; Macrae 1922:62; Douglas 1914:304-305; Stewart 1970:369-371; Ellis 1963:306-308).

Although Goodrich (1826:4) defined this as the zone of cultivation and estimated that 1/20 of the expanse in N and S Hilo was planted with crops, he and subsequent visitors puzzled over the cause of this unwooded area and lamented the lack of more extensive plantings. Being accustomed to agricultural practices in temperate climates, they failed to recognize the need for agricultural patterns adapted to tropical or semi-tropical soils. Due to the tendency of these soils to be rapidly leached of nutrients, particularly in high rainfall areas, and the subsequent dependency of even tropical forests on thick accumulations of organic topsoils or leaf litter, shifting agriculture (i.e., swidden or slash-and-burn) is practiced by most Polynesian and Pacific peoples. In forested areas, this cyclical process involves the opening of the forest canopy, burning of the resulting debris and leaf litter, planting one or more crops either simultaneously or sequentially, and harvesting. When nutrient levels drop below those needed to support further crops, the plot is left fallow, and the entire process is repeated in another plot chosen in either secondary or primary forest.

The process by which forests can be reduced to open grass or shrub lands through either long-term swiddening, or by the repeated effects of intentional and/or accidental fires, has been discussed for New Zealand (Cumberland 1963), New Guinea (Robbins 1963), Indonesia (Geertz 1969), and Hawai'i (Yen 1974:316; Handy 1972:17; Newman 1971:108-111). Changes most frequently occur when, through the shortening of the fallow periods or repeated burning, the forest fails to regenerate, the important organic layer does not accumulate, and soil properties are altered by exposure to sun and wind. The reduced rate of regeneration in semi-tropical environments (e.g., Hawai'i), when compared to truly tropical environments, can accelerate this degradation. The claim that prehistoric Hawaiian land-use practices originally created and subsequently maintained this open landscape can be substantiated by the following six factors:

- (1) The ethnographic records of Kamakau and of Handy and Handy describe the use of fire to initially clear a swidden plot, mixing the ash with the soil as an additional, temporary source of crop nutrients (Handy & Handy 1972:109; Kamakau 1976:31-32). During dry years, such burning could accidentally spread, particularly after a grass or shrub complex replaced the forest. The Hawaiian term *kūla* was applied to the sloping lands without trees between the sea and the mountains.

(2) Contrary to Pickering's shaky conclusion that this lack of forest resulted from "a defect of creation," the presence of the Pana'ewa Forest even in 1823, the abundant stands of economically beneficial trees, the thick growth of trees along the gulches that intersected these grasslands, and the presence today of secondary forests, suggest that a forest was capable of developing on, and did originally cover, most of these slopes down to the coast (Pickering 1840-41: 6).

(3) That extensive areas of rainforest can burn, even in high rainfall areas, was proven when 700 acres of the Pana'ewa Forest and 125 acres of the Waiākea Forest accidentally burned in 1926 after a dry winter (Judd 1937:11-12).

(4) Ledyard, upon entering the rainforest above Kona in 1779, mentioned "those woods that so remarkably surround this island at a uniform distance of four and five miles from the shore" (Ledyard 1963:120). This statement, made during Cook's first visit to the Island of Hawai'i, precludes the possibility that historically introduced practices caused this deforestation. Menzies' placing of the forest four or five miles inland of the N Hilo-Hāmākua Coast further eliminates the possibility that the grazing of feral ungulates induced this grassland, as he accompanied Vancouver when he introduced the founding stock of cattle, goats, and sheep (Menzies 1920:51). An 1851 map of Waiākea Ahupua'a (Fig. 5), reinforces this view, showing the Pana'ewa Forest and the contouring "edge of the woods" between five and six miles from the shore.

(5) The history of sugarcane cultivation along the windward coast substantiates the incapacity of these soils to support a long standing crop due to nutrient deficiencies. Only after the introduction of imported fertilizers could the sugar plantations continue production of yields sufficient to support the foundation and expansion of the industry that dominates the history of the area (Lydgate 1918:78-79).

(6) Some of the major components of the secondary growth complex found in the fallow fields were utilized as major famine foods and as pig foods. The use of fire in utilizing these species during famines, and the accumulative effects of foraging pigs, may have sustained this beneficial community that represents the early successional stages of secondary growth rather than allowing the more advanced plant communities to develop.

A thick matting of grasses composed of several species formed the dominant matrix of the these fallow fields. Dark patches of a small or dwarfed tree fern, a Blechnem or Cyathae (*Sadleria* sp. or 'ama'u) abundantly

covered portions of these grasslands along with lesser amounts of matted Gliecheniaceae ferns (e.g., *Dicranopteris*, *Sticknerus*, *Hicriopteris*) and thick growths of an *Asplenium* (identification uncertain). Several species of Convolvulaceae and *pia* grew throughout most of this expanse (Menzie's 1920: 51; Pickering 1840-41:6-7; Brackenridge 1840-41:30; Wilkes 1845:213; Bloxam 1925:51; Macrae 1922:57; Douglas 1914:298, 304; Ellis 1963:359). In other parts of Polynesia, where shifting agriculture is still practiced, *Dicranopteris* is a recognized, though not exclusive, indicator of human-induced disturbances (Cumberland 1963:201), and *Tacca leontopetaloides*, while occasionally cultivated, mainly grows as a volunteer in upland fields and marginal agricultural lands (Yen 1974:134). 'Ama'u is presently a major component of pioneer vegetation in road cuts, bulldozed areas, and on younger lava flows where adjacent populations still exist.

In Handy and Handy's (1972:183, 234, 235) discussion on wild foods used during times of famine, 'Ama'u, *pia* and Convolvulaceae (morning glories and sweet potatoes) were noted as some of the most important plants gathered. Each is also listed as providing food for pigs; however, the manner of such providing is unclear because of the lack of details about Hawaiian pig husbandry practices. Yen's assumption (1974:315-16) that the grazing or rooting of pigs in fallow agricultural lands was an important food complement to surplus crops (particularly sweet potatoes) may be supported by Macrae and Douglas. Macrae mentioned seeing the dwarf tree fern "whose roots afford food for the swine about the huts of the native" (1922:48) while passing through the grasslands of N. Hilo. Douglas, stopping at a hut between Hilo and probably Mountain View, described a large black pig running from the shade of tree ferns in response to his master's call, after which he was promptly baked (1914:305).

Evidence for the intentional burning within this zone is found in both Macrae and Bloxam. Bloxam described an area south of the study area that "had been burned the last year by fire by design by the natives" without suggesting a cause for such burning (1925:62). Macrae elaborated slightly, when passing from Kea'au to Mountain View, by describing the area as "an open country..., covered with stumpy ferns, chiefly cythea, which the natives often burn during the dry season" (1922:62). An explanation may be implied by Bar-rau's and others' discussions of Melanesian burning of established grass or

shrublands to facilitate the collection of wild tubers and for herding pigs (1958:19). Kirch mentioned the use of burning on the Polynesian Island of Uvea to induce the sprouting and hence the locating of *Tacca leontopetaloides* (1978:179). Possibly the burning of *Sadleria* simplified extraction of its starchy, edible core, as well as inducing the sprouting of feral tuberous plants such as *pia* and Convolvulaceae. The location of "a swineherdershut" by Ellis (1963:307) at Kipuaui, placed between Mountain View and the Volcano by Wilkes (1845:121), thus not far from these burned areas, may reinforce the potential relationship between a selected successional plant community and pig husbandry. Pigs were procured throughout the study area to supply food for ships, overland expeditions, and the noon or evening meal.

The extent of recognizable alteration and thus the possibility of structural remains of the Kīlauea Volcano portion of Zone II is more difficult to reconstruct because few well-traveled routes passed through it. Lyman's (1924:108) visit to the inland village of Waipahoe, presently located on an ash substrate with an old spring, may indicate the potential use of other older substrates isolated by predominately pahoe flows. As many of these pahoe flows are presently covered with *Dicranopteris*, Handy & Handy's reference (1972:540) to the burning of matted ferns (e.g. *Dicranopteris*) before planting in Puna could suggest the use of even these younger flows.

Two large, extensive lava tubes, crossing portions of this zone, contain evidence of probable prehistoric Hawaiian activities. Both run for undetermined distances and contain burials, ash deposits, and shell midden. In the tube closer to the ocean (50-Ha-A1-11), these remains, an assortment of artifacts, and some structural modifications cluster under skylights (i.e., lava tube sinks). Emory hypothesized that the presence of large numbers of sling stones and the uninhabitable dampness of the cave suggest that it was used mainly for refuge during times of war. In the upland lava tube (50-Ha-1-45), entered at c. 800 ft elevation, shell midden and burnt wood fragments occur throughout the tube. Small agricultural terraces and a stepped platform, resembling a shrine, modify a collapse pile where the extended overhang of the skylight makes it impossible to exit without a rope or ladder. This upland tube may have served as a trail to upland resources, as passage through it is relatively unencumbered.

Douglas (1914:309) lists the following different ways in which large caverns or lava tubes were used in Kapāpala, Ka'ū: occasionally as permanent dwellings, as cool retreats for making tapa, as areas for "fabricating and sheltering" canoes, as goatfolds and pig sties, and as gardens where greater amounts of vegetable matter had accumulated compared to the surrounding terrain. Somewhere along the Puna coast, Pickering (1840:177) was shown a shrine built within a cave opening.

Zone III Lower Forest Zone

Use of this zone, from roughly 1,500 to 2,500 ft elevation, revolved around the gathering of forest resources needed for a variety of wood, feather, and fiber products, and for the collecting of supplemental food crops grown in small forest clearings and along streams. This includes the celebrated and specialized crafts of cutting *koa* for canoes and catching birds for feather-decorated objects. Historic accounts suggest that a cluster of small huts, small religious shrines, and numerous paths were frequented by a family unit or group of workers for these purposes. The probability of finding structural or artifactual evidence of these activities appears low due to the temporary nature of the huts and the dense character of the ground cover, which would quickly close unused paths and cleared areas. Streams and springs, the presence of feral cultigens, and tall stands of *koa* could be indicators of greater site probability.

The early historic and present distribution of known Hawaiian cultigens and *koa* places the upper limits of this zone at 2,500 ft elevation. Douglas (1914:61) stated that banana disappeared after 2,500 ft and above the "saw mill," which Brackenridge (1840-41:23) also estimated as at 2,500 ft. This elevation presently marks the upper limit of feral cultigens, such as bananas, taro, and ti, in the Hilo and Hāmākua Forest Reserves (personal observation), and the distribution of low elevation *koa*. As mentioned earlier, *koa* occurs in two disjunct bands; the upper band occurs above 5,000 ft elevation and the lower one below 2,500 ft. Lyons' (1875:111) suggestion that the heaviest general use of the forest took place one-half to one mile above the forest margin, Coan's (1882:46) description of natives collecting timber two miles within the forest above Hilo in 1837, and Handy and Handy's (1972:162) generalization that banana cultivation occurred up to 3,000 ft elevation give alternative estimates as to the extent of this zone.

Plant resources gathered within this zone include those that grew unaided and were established members of the flora in pre-Polynesian times, two non-Polynesian introductions whose growth was directly or indirectly encouraged, and Polynesian introductions that were planted as supplemental food sources and required little or no tending. Examples of valued, unaided species include: 'ie'ie, used in rattan or basketry-type work; 'ōhi'a, koa, and other tree species used for structural timber, carved bowls, religious objects, and firewood; a variety of plants from which dyes and medicines were extracted; and ferns (e.g., *Marattia douglasii* and *Cibotium* spp.), whose starchy cores were baked when food was scarce (Lyons 1875:104; Handy & Handy 1972:56, 234-35).

Olonā (*Touchardia latifolia*) was highly valued for the remarkably tenacious cordage twined from its fibrous bark. Though *olonā* is endemic to Hawaii and grows wild, it apparently was preferable to use selected and tended plants from small plots. Kamakau (1976:53-55) described the procedures for planting and processing *olonā* cordage in Ōla'a. According to Ellis (1965:325) the people of Ōla'a were famed for their fine *māmaki* (*Pipturus* sp.), another fibrous plant that was processed like *wauke* to make a durable and warm barkcloth (Menzies 1920:83). Because *māmaki* can thrive in opened or disturbed understories (personal observation), forest disruptions resulting from the gathering of other forest resources probably promoted its abundance.

Introduced cultigens such as banana, wet and dry-land taro, ti, and yams (*Dioscorea* sp.) were planted along streams and trails and in small patches of cleared forest. Although representing only marginal land use, the importance of a supplemental food source could be substantial for those who occasionally inhabited the forest, as well as being an insurance against drought or crop failure for the general populace. In addition, the leaves of banana and ti provided thatching for huts and were woven into protective caps, rain capes, and wrapping for carried items. Handy described specific planting methods for yams in this zone, based on information given by Puna and Ōla'a informants, but stated that such practices also occurred along the margin of the Pana'ewa and Hilo Forests (Handy & Handy 1972:56, 103, 110, 179, 182, 235, 538). Vague terraces and feral cultigens still remain along the stream leading from Middle Flume Spring at about 2,000 ft elevation (Paul Higashino, pers. comm.).

Descriptions of forest use centered around the selection and hewing of *koa* for canoes and the collection of bird feathers needed to pay mandatory taxes levied by ranking chiefs. The importance of these resources reflects the need for canoes to exploit offshore marine resources and to provide transportation for political and trade reasons, and the use of feathers in highly prized feather cloaks, *lei*, and the decorated objects that still rank as the greatest accomplishment of Hawaiian art.

Most accounts stress the temporary nature of huts within the forest, their use by a family unit, and a division of labor between craft specialties and to a certain extent between men and women. These huts, as well as those along trails, could be quickly constructed or repaired with lashed poles and thatching of ferns, grasses, banana leaves, and ti leaves. Ovens were built for cooking and treating *māmaki* (i.e., to soften the bark and to infuse dyes). Groups mentioned as either working in the forest or encountered there included an entire "family," a husband, wife, and daughter, and a man with two boys. Menzies pointed out that specialization could occur within crafts as well as among different crafts (e.g., those who carved the *koa* trunk initially in the forest did not do the finishing work at the coast). The profession of bird-catching entailed knowing the calls and feeding habits of the desired bird species, the snaring and gumming methods for catching them, and the boundaries dividing political land units. The latter skill made bird-catchers the unequaled guides of early explorers and surveyers.

Both Menzies and Emerson described women, in addition to occasionally helping with the *koa* and feather crafts, as engaged in the production of *māmaki* bark cloth. Both women and men are described as working on *olonā*, again while temporarily residing in the forest. The ability of Ledyard, Samwell, and Menzies to procure pigs from these temporary residents, and Alexander's description of bird-catchers eating *hupu'u* (*Cibotium* sp.) after depleting their food supply, suggest alternatives to surviving entirely on vegetable or marine products brought from the lowlands.

In the comparable zone above Kona, a maze of paths led through an otherwise impenetrable fern and brush understory. Specific paths had to be cut and cleared to facilitate the hauling of *koa* and other cut timber to the

coast, suggesting the probable exploitation of a stand rather than scattered individuals. At undescribed shrines along these paths, the Hawaiians unfailingly stopped to "pray" and/or make perishable or artifactual offerings. Thrum's recording of a canoe builders' and bird catchers' *heiau* in the forest above Hilo (Site 50-Ha-H20-5) may reflect these practices. Menzies observed that considerable thinning and opening of the forest canopy, resulting from the Hawaiian exploitation of timber, occurred along these paths within the forest margin, and with decreasing frequency inland (Lyons 1875: 111; Menzies 1920:81-85, 156, 190; Beaglehole 1967:1166; Ledyard 1963:120; Emerson 1894; Alexander 1953:129; Kamakau 1976:54).

As the association between feral cultigens and terraces at Middle Flume Spring suggests, the presence of streams and feral cultigens constitute areas of higher site potential. Although the process of forest regeneration and historical disturbances can alter concentrations of highly valued species as well as obliterate paths, structural remains could occur with more frequency near stands of *olonā*, *māmaki*, or *koa*. The rare finding of isolated "caches" of artifacts such as adzes, does occur (Site 50-Ha-A1-66, and Rob Hommon, pers. comm.).

Zone IV The Rainforest Zone

Although many of the forest resources occurring in Zone III could be found between 2,500 and 5,500 ft elevation (i.e., within Zone IV), factors such as increased distance from population centers, reduced accessibility due to dense vegetation, habitat preferences of valued plant species, the ethnographic evidence given above, and the discomforts of increasing rainfall and cold at higher elevations, tend to drastically reduce the probability of prehistoric Hawaiian land use and sites. Exceptions to this are the suggested need for bird catchers to shift seasonally with fluctuations in the *'ōhi'a* bloom and the use of at least one major inter-district trail that crosses this zone. Site probabilities would definitely increase adjacent to the trail.

The same climatic factors that restrict the growth of *koa* between 2,500 and 5,000 ft elevation apparently affect the distribution of the other utilized forest plants. *Māmaki*, *'ie'ie*, and *olonā*, while found above 2,500 ft, are far more significant components of the lower forest zone (personal

observation) in the Hilo, Waiākea, and Hāmākua Forest Reserves. Use of the upper *koa* band occurring in Zone IV seems less likely, due to the additional distance needed to haul the partially hewn logs and the greater number of path obstacles that typify these windward forests. The use in 1833 of higher elevation *koa* in the Keauhou forest, south of the study area (Alexander 1953:129), probably resulted from no or few alternate sources for that portion of the district. The growth of Polynesian introduced cultigens, all having developed in tropical climates, may have been restricted in much of Zone IV by the substantially lower temperature. Without these supplementary food sources, in addition to the physical hardships of living in a cold, damp forest with decreasing chances of a burnable wood supply, the potential appears low for even the temporary habitation patterns of Zone III.

Emerson, in his article on Hawaiian bird-catching practices (1894), stated that nectivorous birds in the forest above Hilo seasonally followed fluctuating concentrations of 'ōhi'a bloom "up and down" the forest. The bird catchers, in turn, followed this shifting population unless seeking more sedentary insectivores like 'amakihi or 'elepaio. Temporary residence in these forests supposedly took place during two periods--March through April, and August through October. When not released after capture, these birds provided an edible resource, particularly when the plucking of choice feathers proved debilitating. The use of bird catchers by Lyons and Lyman to determine the *ahupua'a* and district boundaries within this rainforest zone supports the thought that it was utilized (Lyons 1875:111; Lyman 1906:223).

It is nearly impossible to determine the exact location of the early historic and probably prehistoric trail corresponding to the Hilo-Pu'u 'Ō'ō trail and the Saddle Road routes. As substantial portions of both trails follow historic lava flows chosen to facilitate passage and road construction, these two known routes tell little of the earlier routes. The routes taken by Douglas, Pickering, and Brackenridge apparently followed and/or closely paralleled the Wailuku River. Pickering stated that of the two trails available, he and Brackenridge chose the one that followed the stream beds, except for a few detours into the forest. Somewhere in the upper half of the forest, the trail left the river in a SW direction and led to the "Duck Ponds" (probably Waikoloa Ponds). Although Douglas never specifically

mentioned following a riverbed, references to cascades, deep glens, and flood riverlets imply that he followed a similar route. His description of the trail passing over lava and mud, typical of Mauna Loa rather than Mauna Kea substrates, indicates that the trail had to have favored the southern side of the river. The prehistoric legend of Umi's army marching across the upper flanks of Mauna Kea, and muddying the waters of the Wailuku River as they descended for the attack on Hilo, supports the prehistoric existence of this early historic route.

Douglas and Brackenridge both came upon abandoned huts along the trail near the middle or the upper half of the rainforest. These huts, again forming small clusters, were constructed of poles and fern thatching and were similar to those found in Zone III. Both parties complained of a trail made treacherous by mud holes and slick rocks, torrential rains, and a miserable night spent in a fireless hut. The journey's sole consolation was the lush forest "luxuriating in ferns" (Douglas 1914:298, 302-3; Brackenridge 1840-41:24-5; Pickering 1840-41:169-170; Fornander 1916-17:224,228).

The same factors that reduced the possibilities of finding sites in Zone III, such as dense vegetation and the temporary nature of these structures, also apply to Zone IV. Factors such as the less diversified use of this zone, and the implications of overnight visits rather than extended stays, make the overall potential for sites in this zone even lower.

Zone V Subalpine or Montane Zone

Use of major trails, although important to settlement and land use in all zones, probably dominated the utilization of this zone (5,500 ft elevation to the upper limits of the study area, or 9,500 ft). The ease of traveling through these cooler, more open, montane regions and the decreased distances, in spite of exhausting climbs, could have made mountain trails throughout the island invaluable for expedient trade and communication. For lack of any other clues, it might be assumed that the prehistoric trails roughly followed the same routes as the present trails. Resources limited to or more easily obtained in this zone, such as birds and valued hardwoods of the dry or mesic forests, were sought. On the Mauna Loa sections of this zone, sites might be expected along the probable trail routes, near possible concentrations of valued resources such as older substrates with some forest

cover, and on pahoehoe flows providing sheltering lava tubes and overhangs, particularly in areas adjacent to trails or potential resources. The probability of sites in the Mauna Kea portion of the study area is higher along the possible trail route and near ponds or other water sources. However, the high percentage of land covered with historic flows, and the apparently intermittent land-use pattern, result in an overall low probability of sites in this zone.

The earliest accounts, based on second-hand reports, refer to these mountain regions as a vast, uninhabited, and infrequently visited wilderness. By the 1830s, when the first descriptions of this portion of the study area appeared, the following four trails probably merged near the present Waikoloa Ponds or near the junction of these ponds and the Pu'u 'Ō'ō trail: one trail came up from Hilo as described above; one headed N to Waimea (presently the Pu'u 'Ō'ō to Waimea route); one continued S to the Volcano (the Pu'u 'Ō'ō to Volcano route); and one led across the island through the saddle between Mauna Kea and Mauna Loa. The exact location of the last three routes is even more elusive than that of the trail that came up from Hilo, as no distinguishing landmarks are mentioned; this central "junction" area was extensively covered by the 1855 and 1935 lava flows, and the early travelers often spoke of an undefined path leading through great tracts of lava, or one meandering along cattle paths on Mauna Kea.

Other than confirming the existence of these routes, the accounts offer little evidence of prehistoric activities; the historic exploitation of wild cattle and sandalwood (*Santalum* sp.) dominates the discussion of land use. Exceptions are the consistent descriptions of caves used for shelter and as potential water sources, and the possibilities that huts like those used by sandalwood cutters and bullock hunters occurred prehistorically, and that small pools in pockets of lava along the volcano route served as another water source (Pickering 1840-41:171; Brackenridge 1840-41:25; Wilkes 1845:101-102; Douglas 1834:334, 1914:298, 300, 302; Alexander 1953:128-129).

A variety of ethnographic data and early descriptions from similar areas can, however, provide a clear picture of possibly sought resources and land-use patterns designed to exploit them. That montane regions were used prehistorically can be substantiated by the confirmed prehistoric use

of the Mauna Kea Adze Quarry, by more than one legend dealing with battles, marches, and events in this type of setting, and by Menzies' description in 1794 of a similar environment between Hualālai and Mauna Loa (McCoy 1977:231; Fornander 1916-17:224,228; Menzies 1920:163-167).

Within the arbitrary boundaries of the study area, most of the previously discussed *ahupua'a* fell within the districts of S Hilo, Puna and a small portion of Ka'ū. Ōla'a apparently, at one point, formed a separate district, while the lands above roughly 6,000 ft elevation are included in the *ahupua'a* of Humu'ula in the N Hilo district. In his article on Hawaiian political land division, Lyons explained that the idealized intent of an *ahupua'a* division (a district being a compilation of *ahupua'a*) was to create a strip of land, running from the sea to the mountain top, in which an equitable share of ecologically related resources was available to each political unit. On the Island of Hawai'i, however, the usual *ahupua'a* stretched from the shore to somewhere within the rainforest zone, where they were cut off by several larger *ahupua'a* that "expand laterally" to control the vast interior or mountainous lands. Lyons claimed that this expansion took place "by virtue of some valuable product." To exemplify this, he stated that the upper limit of Humu'ula, on the E flank of Mauna Kea, coincides with the upper limit of *māmāne*, a valuable hardwood.

Lyons' explanation defines hardwoods and birds as two important resources of this montane zone. The heavy, fine-grained, and durable qualities of many dry or mesic forest woods made them the preferred material for certain tools (e.g., *māmāne* was one of the woods preferred for adze handles [Judd n.d.]). For windward districts like N and S Hilo, this montane forest provided the only source of such dryland woods, including sandalwood. The sole right to collect 'ua'u (*Pterodroma phaeopygia sandwichensis*, the dark-rumped petrel) on the slopes of Mauna Kea belonged to the people of Ka'ohe, in the *ahupua'a* west of Humu'ula in the district of Hāmākua (Lyons 1875:111). Although the Hawaiians ate both the adult and young dark-rumped petrels, the young were considered a delicacy and were tabu to all but the chiefs. Petrels are sea birds that only come to land during the nesting season; according to Henshaw (1902:130), great numbers of petrels nested in the lava fields between Mauna Loa and Mauna Kea, and bird catchers were sent specifically to gather young. The large numbers of petrel bones found in archaeological cave sites in these

montane regions--on Mauna Kea, in the Pōhakuloa training area, on Hualālai, and above Kona--substantiate the importance of petrels as a supplemental food source for those temporarily utilizing the area, in addition to their being a gathered product (McCoy 1977:231; Rosendahl 1977:Site 50-Ha-D24-22; Dr. J. Michael Scott, pers. comm.). The presence of goose, flightless rail, crow, and small bird bones in some of these deposits suggests that other birds were exploited. Pickering also mentions finding bird bones (goose and hawk?) in lava tubes on the E slope of Mauna Loa.

The presence of glassy crusts on some pahoehoe flows within these regions (Wilkes 1845:101; personal observation) may infer a source of basaltic glass, which, when flaked, presumably served as a cutting and scraping tool.

Menzies' description of the saddle area between Hualālai and Mauna Loa reinforces the importance of caves or lava tubes. As in lava tubes along the coast, water dripping from the ceiling was collected in gourds, and floors or collapse piles were leveled to form sleeping platforms and religious shrines. Substantial midden deposits, fairly extensive modifications, and the Hawaiian guides' knowledge of their locations, suggest repeated utilization of these areas, as does the following quote from Menzies:

...we turned our faces homeward by a path which forms a communication by this valley from one side of the island to the other, and the great cavern which we had just quitted, after lodging in it for two nights, may be considered as one of the inns upon the road for the accommodation of travellers passing between the west side of the island and the east end [Menzies 1920:166].

THE HISTORIC PERIOD

The historical background of the entire study area revolves around the events and changes that took place in what is now the city of Hilo. Due to its position on the bay most suitable for sailing ships and steamers, Hilo dominated the flow of goods and people along the windward coast of Hawai'i. For the period between 1824, when the first missionaries took up residence, and 1946, when damage caused by a tidal wave altered much of the town and finally closed the Waiākea Sugar Mill, four major shifts in the economic and social character of the study area can be delineated from historical records.

During the first period, 1824 to 1848, the still predominately Hawaiian population and culture were being modified to varying degrees by the efforts of Christian missionaries and by increasing opportunities to export agricultural products and other resources. From 1848, when a measles epidemic drastically reduced and dislocated the already dwindling Hawaiian population, to 1865, when the whaling industry began to falter, Hilo was described as a "New Bedford whaling town," catering to increasing demands to supply whaling ships and the California Gold Rush. The next period, 1865 to 1895, saw the change from diversified subsistence agriculture to large-scale, intensified sugar production and managed cattle ranches, accompanied by the influx of immigrant labor. After 1895, major developments supporting the sugar industry (e.g., the railway, the breakwater, and electricity) in addition to the effects of U.S. Annexation of the Hawaiian Islands, further centralized activities around the Hilo area.

1825-1848

Throughout most of this period, cultural use of the study area was still dominated by the essentially Hawaiian practices described in the previous section, although the slow decline of the Hawaiian population and deterioration of Hawaiian religious and political systems resulted in a gradual disappearance of the characteristically Hawaiian landscape. Major causes of this decline were a continuous decrease in the birth rate, increased deaths due to introduced diseases, and increased emigration to developing centers of population and through employment on sailing vessels

and in foreign ports. The greatest changes in the Hawaiian religious and political systems resulted from pressures due to increasing involvement in international trade, world political affairs, and religious movements, exemplified by the effects of the Chinese sandalwood trade and the efforts of the first missionaries to exclude Catholicism.

The general economy remained at a subsistence level, with crop and animal surpluses and available timber products being traded to visiting ships and overland travelers. With the exception of some introduced crop plants, trade revolved around available resources such as hogs, sweet potatoes, and firewood, which were managed in the traditional framework for distributing wealth or material items. Taxes were still levied by the ranking social classes and paid with the feathers, bark cloth, swine, and by mandatory labor. This labor built many of the early historic trails described by visitors, including the Pana'ewa Forest section of the Hilo to Volcano trail, as described by Lyman in 1846 (1924:106).

The first historical event designating Hilo as a focal point for the windward coast was the decision of the American Board of Commissioners for Foreign Missions to station missionaries in Hilo to administer religious and educational programs in the districts of N and S Hilo and Puna. This decision was prompted by factors such as a suitable bay for anchorage, the readily available and reliable source of fresh water, the apparent fertility of the land, and the already existing concentration of people. To achieve their goals, the early missionaries stationed in Hilo created schools and churches staffed by Hawaiians in many villages, introduced new crops and ornamental and adventive plants, and paved the way for other foreigners to establish small commercial ventures. Notable events characterizing missionary efforts in Hilo were the founding of the first vocational school in the United States by Rev. Lyman (Site 10-35-7475), the construction of two New England-style wooden frame houses by the Goodriches and the Lymans (Site 10-35-7454), and Goodrich's attempts to produce coffee and sugar from small plantations. Other foreigners, including several of Chinese ancestry, expanded the production of sugar and coffee, began to serve as middlemen in the increasing flow of introduced and exported goods, and established a temporarily successful "sawmill."

While most of these additional land-use practices of the historic period occurred in Zones I through III, the exploitation of feral cattle and sheep dominated the use of Zones IV and V. Introduced by Vancouver in 1792 and protected by a ten-year prohibition from hunting, these feral ungulates quickly populated the interior regions of the island, particularly the sub-alpine zone along the NE and E flank of Mauna Kea. When the prohibition ended, those who gained permission to shoot cattle on lands they controlled began to export jerked (salted) meat, tallow, and hides. The building of wooden driving pens and sunken traps, the introduction of Mexican cowboys in 1832, and increasing efforts to restrict use of the diminishing herds through branding, taming of selected stock, and restrictions on "wasteful" cattle by-products, marked the early transitional stages from poorly regulated hunting to the modern ranches found today. Although most of these activities were concentrated in the Waiamea-Kawaihae area of the Island of Hawai'i, by the 1830s substantial amounts of hides, jerked meat, and tallow were exported from Hilo. These goods were procured and processed near pens and huts in the vicinity of the Waikoloa Ponds and at several sites N of the study area, and subsequently transported to Hilo via the Pu'u 'Ō'Ō to Hilo trail route.

Between 1837 and roughly 1840, a "great religious revival" occurred within the jurisdiction of the Hilo Mission Station, under the appointed preacher Titus Coan. This series of intense religious meetings, mass conversions, and pilgrimages, though probably related to the general upheavals in the Hawaiian culture, were ignited by a Puna man's "vision" and the destructive 1837 tidal wave that destroyed a portion of the village along Hilo Bay. During the revival's height, as many as 10,000 people congregated in Hilo at one time. Among other consequences, this led to the severe alteration of traditional habitation and garden sites within the Hilo area, the permanent or temporary abandonment of entire villages in outlying areas, and a deeper disruption of traditional Hawaiian beliefs and subsistence patterns. Although the methods and value of such revivals in Hilo and elsewhere were criticized and discouraged by some church leaders, Coan blamed the Wilkes Expedition's three-month stay in Hilo (1840-1841) for his congregation's eventual loss of religious fervor and for the disruptions of some traditional practices. The mobilization of a labor force to supply and transport food

and other necessities for the various exploring and recording tasks performed by the Wilkes Expedition helped establish a salary-based economy and promoted trade concepts.

The overall distribution of sites and potential for unknown sites from this period resemble that of the prehistoric period, with the exception of intensified use of Mauna Kea portions of the subalpine zone and upland trails due to exploitation of feral cattle. Most structural remains of this time period also resemble those constructed and occupied during the prehistoric period, with the presence of historic debris such as glass and metal as a major distinction. Trail construction, reflecting the increasing use of mules and horses, included the additions of curbstones, small ramps, walled and filled depressions, and straighter, more inland-tending routes (Apple 1965:65). All the early wooden framed structures have fallen to decay or fire.

1845-1865

Within this time span, the continuous complex of Hawaiian huts and gardens along Hilo Bay was replaced by a village of predominately wooden-framed structures, concentrated in the N half of the bay between the Waialama and Wailuku Rivers. The main pier near the mouth of the Wailuku River served as the focal point of this "New Bedford" type whaling town of trading stores, stables, churches, small boarding houses, and residences. A few huts and wooden frame houses formed a separate fishing village S of the Wailoa River, while gardens and an increasing number of sugarcane fields covered portions of the upland slopes. Along the Puna coast and in Ōla'a, agricultural products for trade and subsistence still dominated life in the reduced number of villages containing fewer people.

The major catalyst for this transformation was a series of severe epidemics that drastically reduced the Hawaiian population with their low resistance to foreign diseases. In 1848 a measles epidemic began in Hilo and spread throughout the island, killing an estimated one-third of the population. The epidemic of smallpox that followed in 1853, and later outbreaks of leprosy and plague, not only further reduced the population, but also disrupted the routine subsistence and traditional practices of those left to tend the sick and dying. As a result, more villages, habitations,

and gardens were vacated, remnant populations relocated to towns and villages with an economy based increasingly on foreign trade, and knowledge of traditional Hawaiian beliefs and practices was gradually lost or was retained by only a few. Traditional land tenure policies were further upset when a series of governmental rulings in the late 1840s and early 1850s introduced the concept of private ownership of land, opening possibilities for both Hawaiians and foreigners to own and sell land.

Supporting the establishment of this export economy and the accompanying New England-type town was the expansion of the whaling industry, most of which originated in New England. After Honolulu and Lahaina, Hilo Bay ranked as the third most-frequented port-of-call for whaling ships needing food (e.g., sweet potatoes, jerked beef, hogs, sugar, etc.) and wood for stoking fires and making repairs as they hunted whales on their Pacific runs. Adding to this general boom was the rapid influx of people into California during the 1849 "Gold Rush" and their need for similar supplies.

The exploitation of cattle and sheep continued to become more formalized as attempts were made to fence or wall portions of grazed lands. This resulted from the legal establishment of boundaries between privately owned and government-controlled lands and from needs to control grazing and to isolate the new breeds of cattle that were being introduced to improve the original stock. In 1856 an informal sheep ranch was established near Humu'ula to utilize a portion of the feral sheep population, mainly for wool.

During the first half of the 1860s, the Hilo area and the Kingdom as a whole underwent an economic depression following a steady decline in the whaling industry. The replacement of whale oil by the newly developed kerosene products, the substantial number of whaling ships sunk by the Confederate Navy during the Civil War, the growing scarcity of whales, and the need to hunt them in remote arctic waters subject to hazardous ice formations, all contributed to this decline. Four sugar plantations were established in the N and S Hilo districts by 1865, providing the foundation for the next industry to dominate the economic life of the study area.

As with the previous period, none of the wooden structures characteristic of this period have survived. The modification and expansion of trail systems continued to accommodate horses, donkeys, and mules. Walls and the

establishment of ranch sites from this period provide a potential for historic sites in the upland zones. Possible agricultural features surviving from this time would be difficult to distinguish from those of early and later periods.

1865-1895

By 1874, Hilo ranked as the second largest city in the islands, as a result of its central position in the rapidly expanding and intensified sugar industry at Waiākea and along the N and S Hilo coast. Not only were the number of mills, plantations, and acres planted increasing, but with the introduction of new sugarcane varieties, the practice of wide-spread fertilization, and more efficient mill equipment, more sugar could be produced per acre. Accompanying this expansion was the spread of businesses directly or indirectly catering to the sugar industry all along Hilo Bay, the establishment of scattered plantation towns, and the immigration of a labor force to supplement or replace the declining Hawaiian population.

Encouraged by the trade reciprocity treaty with the United States in 1875, expanding business concerns produced the capital necessary to purchase new equipment for the mill and fields and to establish middlemen and warehouses for the influx of goods. Flumes were built to capture water from lower forest streams and carry the cut cane stalks from the upland fields to the mills. However, the bringing of "contract laborers"--from China in 1852, from Portugal in 1878, and from Japan in 1885--changed the eventual character of the study area more than any other set of events.

Sheep and cattle ranching continued to become refined and to expand with the establishment of ranches in such lowland areas as Shipman's property in Kea'au. Other examples of business, not directly related to sugar cultivation, were the continued use of the Waiākea fishponds, an active Chinese fish market, small pastures above Hilo supporting dairy cattle, and scattered vegetable gardens.

Lowland trails, particularly near population centers, were widened to accommodate increased traffic and use of carriages and oxen, while routes throughout the forest remained unchanged. Agricultural features, possibly

dating from this period, could occur on lands adjacent to those now utilized. Many peripheral areas were abandoned when modern planting and harvesting machines could not operate on steep slopes or under less uniform conditions. Ditches dug to supply the early flumes with water are still evident along the lower edge of the forest. As with previous periods, few wooden structures remain.

1895-1946

Almost all of the historic-period sites listed in Table 1 were constructed between 1895 and 1946 and reflect the continued dominance of the sugar industry, major capital improvement expenditures that further centralized activities in and around Hilo, and the varying religious and cultural activities of the different immigrant groups that by this time constituted most of the population. With relatively minor interruptions caused by the two World Wars, the modernization, centralization, and diversification of businesses characteristic of this historic period continued until 1946, when damage caused by a severe tsunami closed the Waiākea Mill, the railways, and, temporarily, major portions of the city of Hilo.

Between 1898 and 1924, a series of attempts to diversify the types of agricultural and timber products exported from the study area eventually proved unsuccessful, reinforcing the dominance of the sugar industry and the secondary role of cattle ranching. In 1898 government land in Ōla'a was divided into homesteads to foster a projected coffee industry which, due to drops in the international price of coffee, a severe blight, and a poor choice of farm plots, barely lasted two years. Coffee grown more successfully in seaward and southern portions of Puna could only support a small mill until 1924. Other industries that either temporarily flourished and folded or never survived beyond the initial investment were 450 acres of pineapple near Kea'au, the production of starch from *hupu'u* (*Cibotium* spp.) and cultivated manihot, the exportation of 'ōhi'a railroad ties, shingles, and lumber from a mill near Pahoa, and proposed rubber and tobacco plantations. Most of the land utilized during these attempts was purchased or leased by sugar interests and is now under sugarcane cultivation.

Many of these economic ventures and those strengthening the sugar industry were supported by increasing capital and trade opportunities resulting

from the Annexation of Hawai'i to the United States in 1898, followed by the granting of Territory status in 1900. U.S. government funds commissioning the building of the Hilo breakwater, beginning in 1908, improved anchorage and wharf conditions enough to firmly establish Hilo as the focal point for exported and imported goods and accompanying mercantile operations. The establishment of the Hawaii Consolidated Railway in 1900, funded directly and indirectly by sugar profits, and its extension by 1913 from the Waiākea Mill and wharf through Puna, most of Ōla'a, and along the N and S Hilo coast, continued to concentrate economic activities. People previously isolated in plantation towns, and dependent upon facilities and services provided by the plantations, had the option of riding to Hilo for business or recreation.

Although immigration continued through the early 1900s, Annexation nullified many of the labor contracts binding immigrants to the plantations, thus giving many the opportunity to settle in Hilo or other towns and establish businesses of their own. These not only competed with existing establishments but created new specialty shops and services catering to the different ethnic groups. This exodus of plantation labor, mostly to the city of Hilo, prompted the recruitment of labor from the Philippines in 1906. Many people who had come from the U.S. Mainland to farm the unsuccessful Ōla'a homesteads eventually moved to Hilo and contributed to its increasing diversity (e.g., a newspaper and drugstore). With the introduction of electricity in 1895 and the designation of Hilo as the county seat in 1905, Hilo was still the second most populated and "modern" city in the Territory of Hawai'i.

With the 1914 purchase of Humu'ula Sheep Station by Parker Ranch, Parker and Shipman Ranches controlled, through leases or ownership, most of the grazing lands in and adjacent to the study area. New species of pasture grasses were introduced to improve livestock feed, as well as new breeds of cattle. Shipman Ranch land between the Pana'ewa Forest and Kapoho was burned regularly to retain grass as the dominant ground cover. The establishment of the Hawaii Meat Company in 1909 gave these and other ranches an outlet for their product. Most historic walls, ranch houses and accompanying facilities, and trails such as the Pu'u 'Ō'Ō Volcano trail, the Humu'ula Sheep Station Wall, and Pu'u 'Ō'Ō Ranch were either constructed or most intensively utilized during this period. A substantial amount of grazing land adjacent to Hilo or to sugarcane fields supported dairy cows for Hilo's several dairies.

In the 1920s most of the remaining rain forest between the sugar-cane fields and the upland pastures was designated as forest reserve. The importance of maintaining a forest as a "watershed" to capture, retain, and support the continuous flow of water necessary to the sugar industry (e.g., to supply flumes with water) as well as the city, was recognized throughout the Territory. These reserves were fenced, and the feral cattle that had caused severe damage to the forests were actively hunted and removed. Hunting of feral pigs, as a sport, continued within these reserves after most of the cattle were removed. Up to this period these forests were exploited by bird catchers, who were able to find a market for feathers even after the disappearance of traditional Hawaiian feather crafts. The use of guns in addition to traditional snaring methods, however, increased their efficiency and contributed to the extinction of certain preferred species (e.g., *mamo* and 'ō'ō), which were already facing environmental stress.

World War I and the international depression of the early 1930s slowed the general trends of this period, but did not result in any major shifts in land use or in the population distribution in the study area. By 1934 automobiles and accommodating roads were well established, regular inter-island air transportation had begun, tourism was gaining recognition as a significant part of the economy, and, in 1936, Hilo's first radio station was transmitting.

World War II had a more dramatic impact on the area, with the stationing on military troops in the city and other parts of the island, the utilization of some plantation labor in military or related activities, and construction projects such as the General Lyman Airfield, the Saddle Road linking Hilo directly with the leeward coast, and defensive bunkers and gun emplacements.

The Statewide Inventory of Historic Places listed and evaluated a comprehensive selection of sites from this period; hence, potential is low for structures or sites that are still unknown. Poorly represented in the Inventory are areas in the forested and subalpine zones that reflect the use of trails, the tapping of rivers and springs for flumes and general water needs, certain aspects of ranching such as walls, driving pens, and water holes, and remnants of military activities during World War II.

RECOMMENDATIONS FOR A SURVEY DESIGN
AND FURTHER STUDY WITHIN THE INTENSIVE STUDY AREA

The intensive study area is an elongated corridor, 197.16 km long and of varying width, extending from the coast to roughly 5,500 ft elevation (see Fig. 6). The entire area (c. 10,716 ha.) is on the flanks of Mauna Loa; it includes substrates with organically and ash-derived soils, and spans two of the major vegetation zones (submontane, and the montane rainforest) and four of the major land-use zones that were described in a previous section. Based on rough estimations from 1977 aerial photographs, 2,884 ha. of the study area (27%) appear to have been severely altered by historic-period practices in agriculture, forestry, and light industry, while 1,303 ha. (12%) are covered by historic-period lava flows.

At least two legends are set within the intensive study area:

(1) Older residents of Kea'au tell of a siren who lived within the Pana'ewa Forest, although no exact location is given. By mimicking familiar or appealing calls, the siren would entice the unsuspecting into the forest and disorient them until they became lost.

(2) According to some sources (Kamakau 1964:16; Hudson 1932:297; Loo and Bonk 1970:65), one of the most significant incidents of Kamehameha's rise to power was a skirmish that took place at Pāpa'i Bay. Upon going ashore, Kamehameha caught his foot in a crevice, and an opponent struck him with a canoe paddle. As a result, Kamehameha issued his famous *māmala hoe* law (the "law of the splintered paddle") to guarantee the safety of all travelers by providing for the severe punishment of violators. Thus, the major trail leading around Hawai'i Island was called the Māmalahoa Trail, and the law became a symbol of justice and protective benevolence.

Of the 17 recorded archaeological sites located within the intensive study area, 15 were described by Hudson in 1932 (50-Ha-A1-49 through -63) and two by Ewart and Luscomb in 1974 (50-Ha-A1-37 and -38). The sites recorded by Hudson, including enclosures, platforms, and outcrops modified by walls, appear to cluster around Pāpa'i Bay, within a kilometer to the north. All are located along or within 260 meters of the coast. The two walls described by Ewart and Luscomb were given minimal significance ratings and lie within 150 meters of the Hilo-to-Puna Trail.

In 1977 and 1978, while employed by the U.S. Fish & Wildlife Service as a botanical aide, the author walked 13-1/2 of the 20 transects flagged for the Hawai'i Forest Bird Survey. Spaced two miles apart, each transect ran on a compass bearing from *mauka* to *makai* through the rainforests (average 6,000 to 2,000 ft elevation) on the windward flanks of Mauna Loa and Mauna Kea. Of the four transects that cross the intensive study area, no sites were noticed on the two walked by the author, covering sections four miles apart between 4,400 ft and 3,400 ft elevation. James D. Jacobi and F. R. Warshauer reported no obvious structural remains from the other two transects, nor were any found while surveying land that is analogous to the intensive study area. However, feral cultigens that denote probable prehistoric activity, and ditches and wooden frames associated with late-eighteenth and early-nineteenth century flume systems, do occur in some areas below 2,500 ft.

No historic-period sites listed on the Federal or State Registers of Historic Places are located within the intensive study area, nor were any sites evaluated within this area during the Statewide Inventory. However, two historic sites (Hawaii Consolidated Railway, 'Ōla'a Flume) and three historic trails (Hilo-to-Puna, Hilo-to-Volcano, Hilo-to-Pu'u 'Ō'ō) cross the intensive study area. Considered by the author to be worthy of recognition, these sites are listed at the end of the inventory and located on the U.S.G.S. maps that accompany the report.

No systematic sampling design or specific method, other than total coverage, has been attempted or evaluated for any large-scale survey in Hawaiian archaeology. Thus, the following recommendations for a cultural resource reconnaissance are primarily based on regional archaeology studies (i.e., generally dealing with an area greater than 50 km) utilized in the continental United States. Most address the problem of collecting, under constraints of limited time and financing, diverse data adequate to form a basis for making planning, management, and research decisions (Judge et al. 1975; Schiffer et al. 1978).

A multi-staged sampling design, in which sampling in the initial survey stage is stratified by prehistoric and early historic-period land-use zones, appears to be the method best suited to the diverse biotic and geologic character of the intensive study area and the limited amount of previous archaeological work. By the use of linear transects, each of these

land-use zones can be stratified by substrate variations and major vegetation types, where known. A systematic-interval transect method is proposed for Zone I, where the substrate appears relatively uniform; transects in the remaining zones, although plotted mainly to sample substrate variations, should be spaced with some degree of regularity to insure coverage of elevational or N-to-S variations within each zone.

The purpose of a multi-staged research design, in this case a two-staged survey, is to allow, during the first stage, for an efficient overview of the area's cultural resources, their distribution, and the problems involved in detecting these resources. Based on the resulting data and an evaluation of the sampling methods, the principal investigator can, while still in the field, formulate a design for the second stage to maximize the probability of discovering cultural resources or answering particular planning or research questions (Judge et al. 1975:88, 89, 119; Schiffer et al. 1978: 16, 17). For example, if a certain substrate type were tranversed, no sites were found, and the accompanying vegetation type drastically reduced site detection and observer mobility, then this substrate and vegetation type could be eliminated from further studies. On the other hand, if a transect crossed the edge of a large site complex and the data collected along the narrow path of a transect was not sufficient to answer certain questions, such as the relationship or abundance of site types clustered within the complex, then this specific area could be re-sampled during the second stage by different, more time-consuming methods tailored to these questions.

The defining and describing of major land-use zones (see pp. 14-33) within the study area indicates that prehistoric and historic use of the environment was not uniform, and that the intensity of land use and the types of cultural remains reflecting these patterns vary with each major zone. Therefore, the sampling design for the entire intensive study area can be stratified by major land-use zones, with the degree of coverage and the probability of sites increasing in direct proportion to the intensity of known land use. With the use of transects, interval width and the total number of transects within each zone control the degree of coverage. As an example, the suggested sampling of Zone II (Upland Agricultural Zone), originally characterized by scattered huts and agricultural plots or fields, would be more intense (i.e., more transects, spaced more closely) than that proposed

for Zone III (Lower Forest Zone), where huts constructed primarily of perishable materials were used only on a temporary basis.

Simple transects placed perpendicular to the dominant lava flow patterns (except where prohibited by access problems) are recommended because this method has demonstrated a high probability for efficient recovery of diverse and accurate data for large tracts of land. Alternative methods, such as quadrant or random sampling, are less efficient, particularly in rough or heavily vegetated terrain, due to the excessive amount of time needed to locate and mark these plots or points. Comparative experiments, as well as evaluation of sampling results, suggest that data collected on transects usually approximate that obtained from more complicated surveys, while increasing the probability of finding a wider range of material (Judge et al. 1975:120; Schiffer et al. 1978:11, 12).

In this case, where successive Mauna Loa lava flows have created a highly variable mosaic of substrate types, ages, and corresponding vegetation complexes, random or set-interval methods of choosing transect locations can be rejected, as both might emphasize substrates that are not well suited to cultural adaptation or vegetation types that reduce site detection. This consideration, as well as the "patchy coverage" of some random designs, makes a stratified sampling design more applicable and efficient in terms of enhancing the probability of locating sites (Judge et al. 1975:121; Schiffer et al. 1978:12). The tendency of known archaeological sites and early historic villages to occur with certain substrate types further emphasizes the need for a stratified sample. Whenever possible, the choice of strata should be arranged to sample possible variation within each zone due to elevation or orientation, generally giving the transects interval appearance. Suggested walk-through reconnaissance techniques include following transect lines on a compass bearing, plotting transect locations on aerial photographs and maps as accurately as possible, and recording, by standard archaeological procedures, any sites or cultural material found.

The following paragraphs briefly summarize and exemplify sampling recommendations as they apply to the four major land-use zones within the intensive study area. As the lava control project is in the early planning stages, location of possible structural control measures and the corridor of possible impact (i.e., the intensive study area) is still subject to change. Thus, no attempt will be made to specifically locate proposed transects, elaborate on sampling methods, or calculate estimated field time or costs.

The soil substrates mentioned below were defined and delineated by the Soil Conservation Service (1972) while the vegetation units used in Zones III and IV were mapped by James Jacobi (Mueller-Dombois 1977). As more accurate and comprehensive vegetation maps are currently being prepared by the U.S. Fish and Wildlife Service and more refined geological maps are being compiled under auspices of the U.S. Geological Survey, information from these maps, if available, should be utilized to determine the sampling strata. Table 1 summarizes by major land-use zones (in hectares) areas suitable for sampling and areas that can be eliminated, where severe land modification has most likely destroyed any potential cultural resources. Estimates were based on information from 1977 U.S. Geological Survey aerial photographs in which land is obviously under cultivation or has been bulldozed for exotic tree plantations, cleared for light industrial or other uses, or covered by historic lava flows.

Table 1.

AREAS TO BE SAMPLED WITHIN MAJOR
LAND-USE ZONES, INTENSIVE STUDY AREA

CULTURAL LAND-USE ZONES	AREAS TO BE SAMPLED (ha.)	ELIMINATED AREAS		TOTAL (ha.)
		IN AGRICULTURAL, FORESTRY, OR INDUSTRIAL USE (ha.)	HISTORIC LAVA FLOWS (ha.)	
ZONE I COASTAL SETTLEMENT	433			433
ZONE 2 UPLAND	1846 (44%)	2306 (56%)		4152
ZONE 3 LOWER FOREST	1003 (64%)	560 (36%)		1563
ZONE 4 RAIN FOREST	3247 (71%)	18 (0.5%)	1303 (28.5%)	4568
TOTAL	6529	2884	1303	10716
PERCENT OF TOTAL	61%	27%	12%	

Zone I Coastal Settlement

As no known features or characteristics mark the upper limit of this zone, the arbitrary limit of one mile from the coast has been chosen. As the substrate appears relatively uniform (pahoehoe with little or no soil development), transects could be placed at set intervals with the number and spacing reflecting the high site probability that is characteristic of this zone.

Site probability is increased by the presence of a bay (Pāpa'i) suitable for fishing, the historic Kamehameha legend implying the existence of some inhabitants, and the apparent clustering of sites listed by Hudson. At the same time, however, the apparently less favorable substrate type (i.e., younger pahoehoe) in this section reduces the probability of a major

village complex like Kahuwai, S. Puna. It is suggested that no attempts be made to relocate these sites, especially during the first survey stage, as they are either of minimal value or have not been recorded and precisely plotted since 1932, and survey time could be better spent. All of this zone's area (433 ha.) can be included in the sample design.

Zone II Upland Agricultural Zone

Of the 4,152 ha. included in this zone, 1,846 ha. (44%) appear to be undisturbed, while 2,306 ha. (56%) have been completely altered. In spite of the generally high site potential for this zone, the consistent descriptions found in early historical journals of an undisturbed Pana'ewa Forest (which covers most of this section of the study area) reduce the overall site probability. On sections of ash-capped substrates, the probability of sites may increase, as exemplified by the presence of the Honua Hawai'i Complex on adjacent land. That the probability of sites should rise along either of the prehistoric/historic trail routes is reinforced by Ewart and Luscomb's description of two sites near the Hilo-to-Puna trail. Any remains of the Hilo-to-Puna trail, the Hilo-to-Volcano trail, and the Hawaii Consolidated Railway should be inspected and evaluated as historic sites, as they were not included in the Statewide Inventory. Six different soil types have been defined in this zone, with thin stoney organic soils underlain by aa (two types) and pahoehoe (one type) predominating. Most areas of the ash-derived soils are planted in sugarcane. At least two areas of each of the three major soil types should be sampled during the first survey stage at different elevations. The thick vegetation and rough terrain described by Ewart and Luscomb (1974:11) may reduce the probability of site discovery by affecting the mobility of observers and obscuring site detection.

Zone III Lower Forest Zone

The low intensity of use of this zone implied in the ethnographic and early historic literature, combined with the low potential for structural remains, allows for a reduction in the number of transects needed to adequately sample this area. Within these 1,563 ha., roughly 560 ha. (36%)

should be eliminated from the design. Most of this zone is characterized by thin organic soils covering aa and pahoehoe, with the exception of two fairly large deposits of weathered ash. The section of Zone III included on the vegetation map indicates an open 'ōhi'a-koa forest with a *Cibotium* understory. Forests of this type are generally easy to traverse, although the presence of large numbers of pigs in this area (Griffin 1972) may have disrupted cultural remains, as has been observed in Kona, particularly on ash-capped substrates (personal observation). Remains of the inoperable 'Ōla'a Flume should be recorded and evaluated in the light of further historical research.

Zone IV Rainforest Zone

Although the probability of finding sites in this zone is exceedingly low, due to minimal prehistoric and historic land use, coupled with the dominance of a vegetation type characterized by an open canopy and an understory of matted ferns mixed with shrub and herbs on poorly drained substrates, areas incorporating three organically derived soil types and two ash soils can be sampled. This stratification can be supplemented with four areas of additional vegetation types that are generally more conducive to survey. This is particularly true in the corridor section that encompasses the Saddle Road, where portions of the historic Hilo-to-Pu'u 'Ō'Ō trail may still exist. Of the total 4,568 ha., 3,247 ha. (71%) can be included in the sampling design, while 18 ha. (0.4%) and 1,303 ha. (28.5%) are covered by historic lava flows.

APPENDIX

The following persons were interviewed for their knowledge of the study area:

- * Mr. and Mrs. Roy Blackshear (Shipman descendants)
- * Margaret English (Shipman descendant)
- * Virginia Goldstein (Department of Planning, County of Hawaii, and anthropologist)
- * Violet Hansen (Bernice P. Bishop Museum Field Associate, Anthropology)
- * John Healy (Geographer, University of Hawai'i at Hilo)
- * Paul Higashino (Botanical Aide, Division of Forestry, State of Hawai'i)
- * James D. Jacobi (Botanist, U.S. Fish & Wildlife Service)
- * John P. Lockwood (Geologist with U.S. Geological Survey)
- * Robert Maglason (U.S. Soil Conservation Service)
- * Herbert J. Mann (Anthropologist)
- * Charles Okino (State of Hawai'i Survey Office)
- * J. Michael Scott (Director of U.S. Fish & Wildlife Service, Hawai'i Forest Bird Survey)
- * Margaret Shipman (Shipman descendant)
- * F. R. Warshauer (Botanist, U.S. Fish & Wildlife Service).

The author was not able to meet with the following persons, but because of their extensive knowledge they should be interviewed during any further study:

- * Thomas W. Lindsey (Retired foreman, Shipman Ranch)
- * William Subica (Puna Sugar Company Supervisor).

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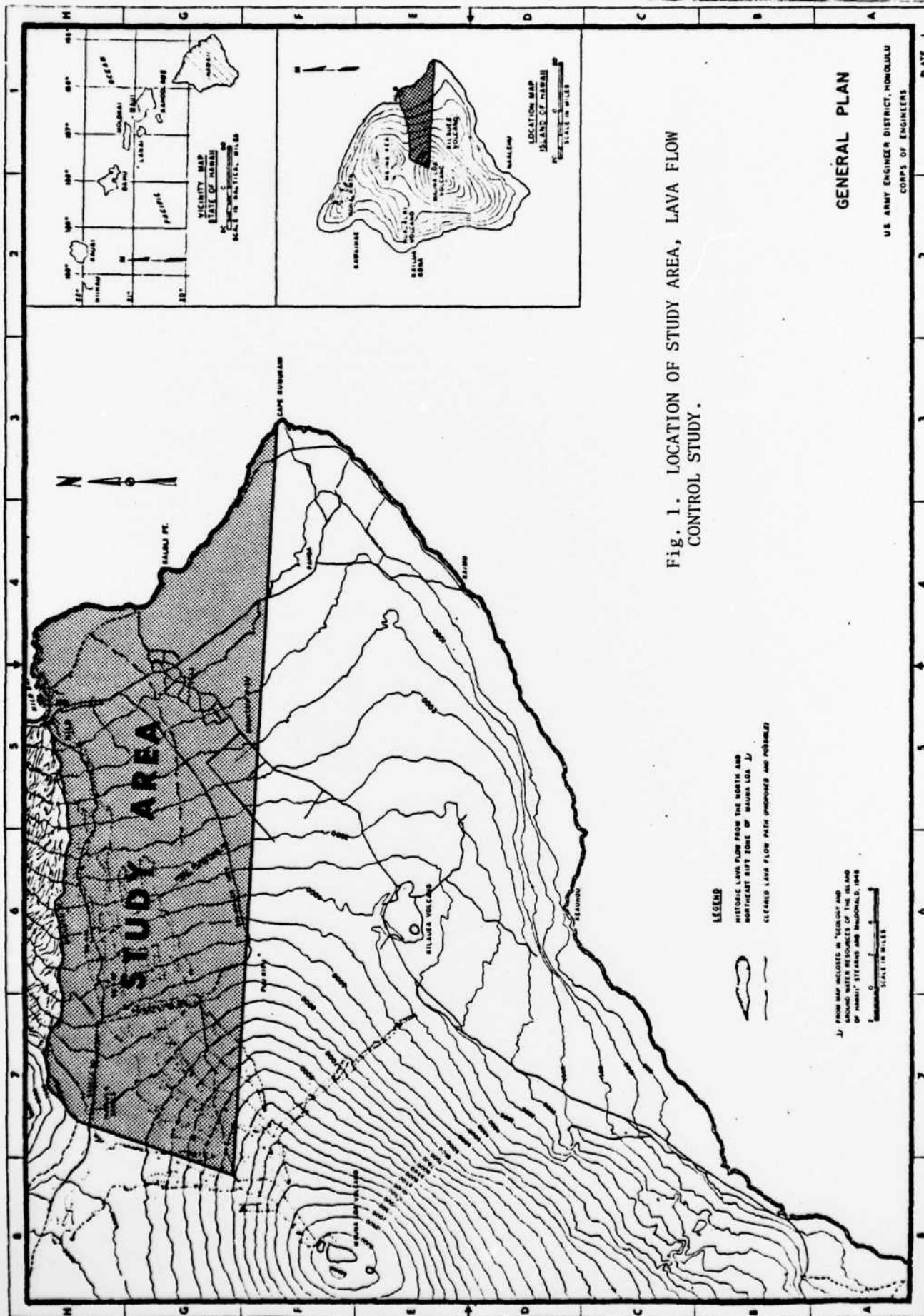


Fig. 1. LOCATION OF STUDY AREA, LAVA FLOW CONTROL STUDY.

GENERAL PLAN

US ARMY ENGINEER DISTRICT, HONOLULU
CORPS OF ENGINEERS

PLATE 1

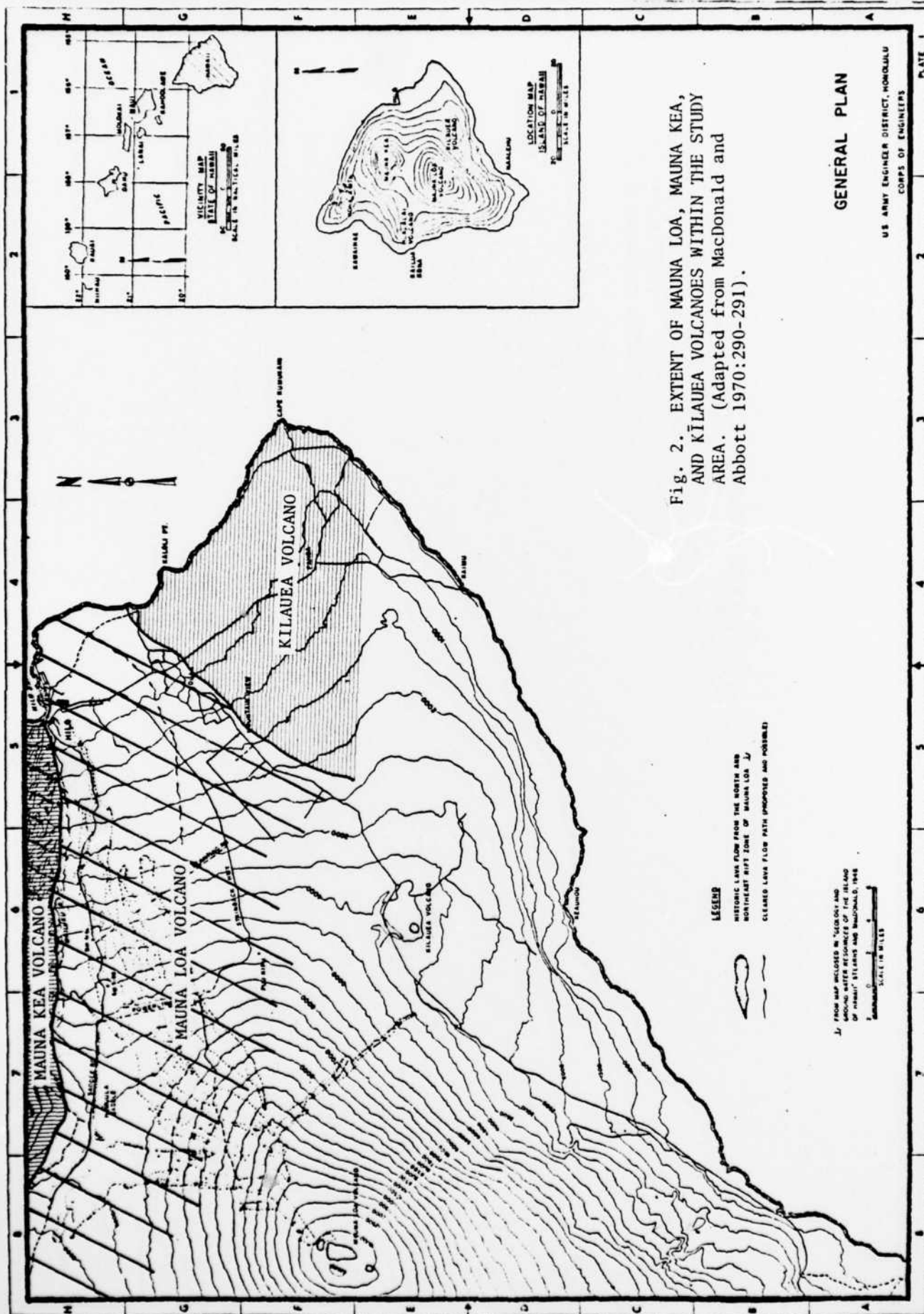


Fig. 2. EXTENT OF MAUNA LOA, MAUNA KEA, AND KĪLAUEA VOLCANOES WITHIN THE STUDY AREA. (Adapted from MacDonald and Abbott 1970:290-291).

GENERAL PLAN

U.S. ARMY ENGINEER DISTRICT, HONOLULU
CORPS OF ENGINEERS

PLAYE -

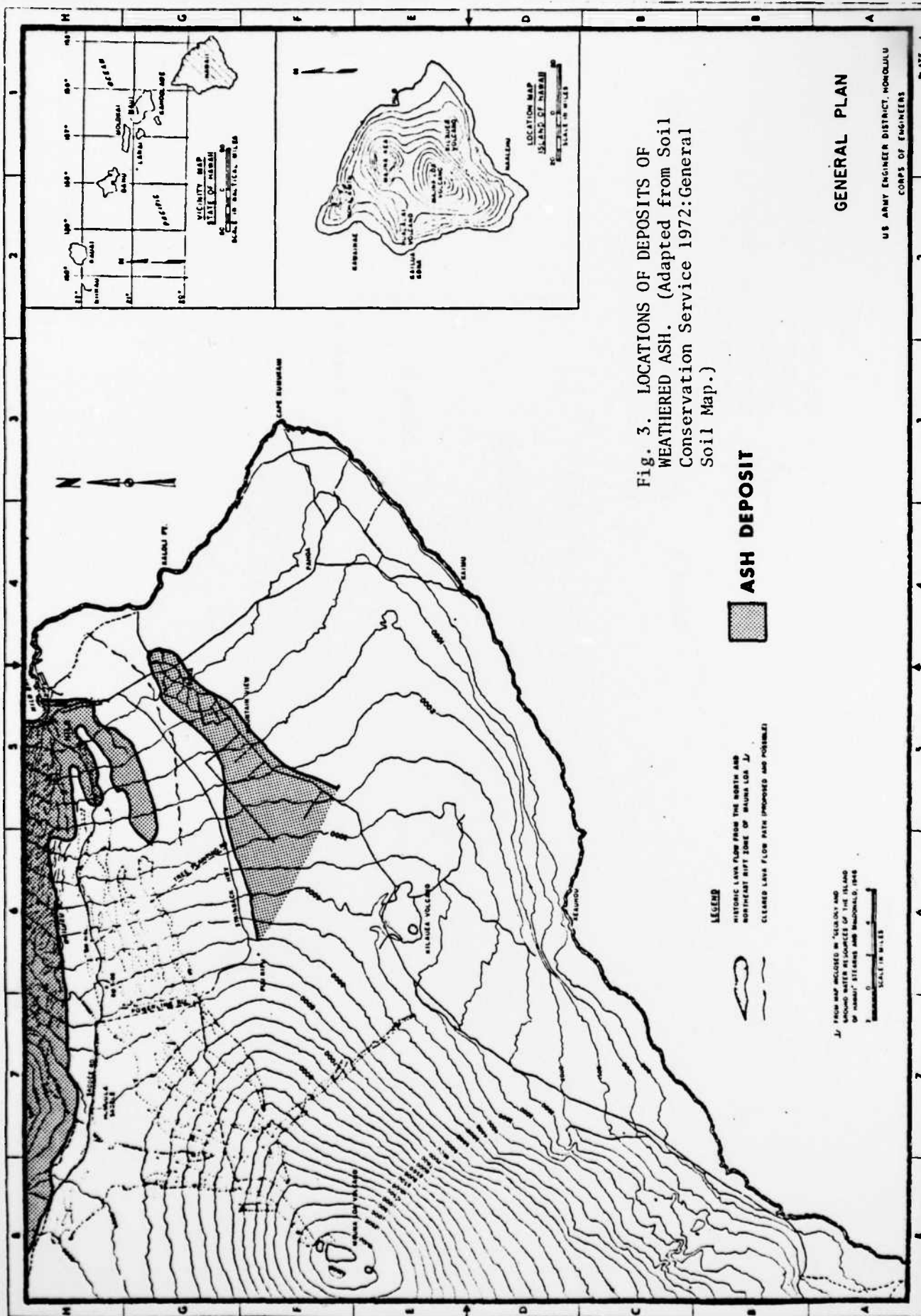


Fig. 3. LOCATIONS OF DEPOSITS OF WEATHERED ASH. (Adapted from Soil Conservation Service 1972:General Soil Map.)

GENERAL PLAN

US ARMY ENGINEER DISTRICT, HONOLULU
CORPS OF ENGINEERS

PLATE 1

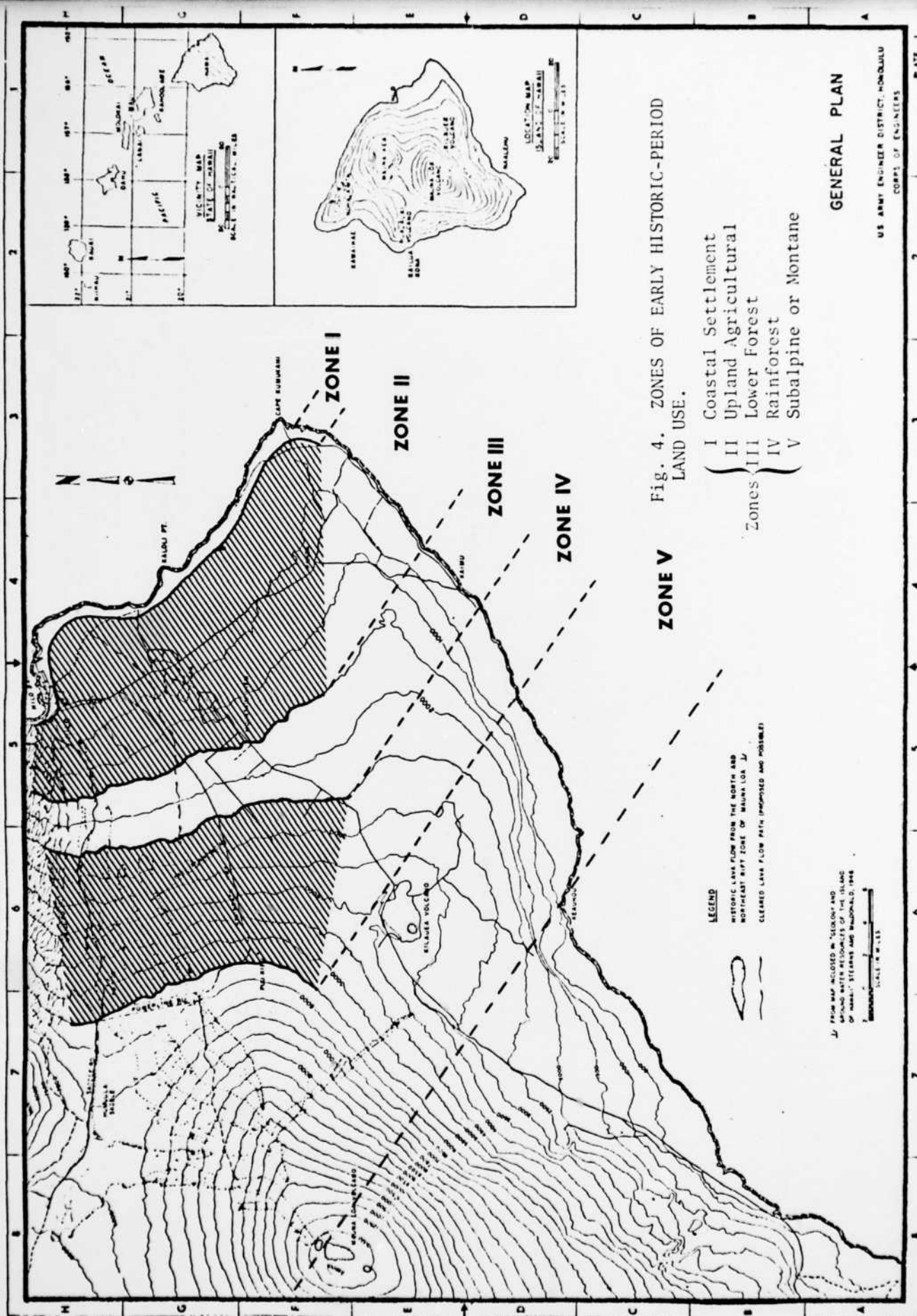
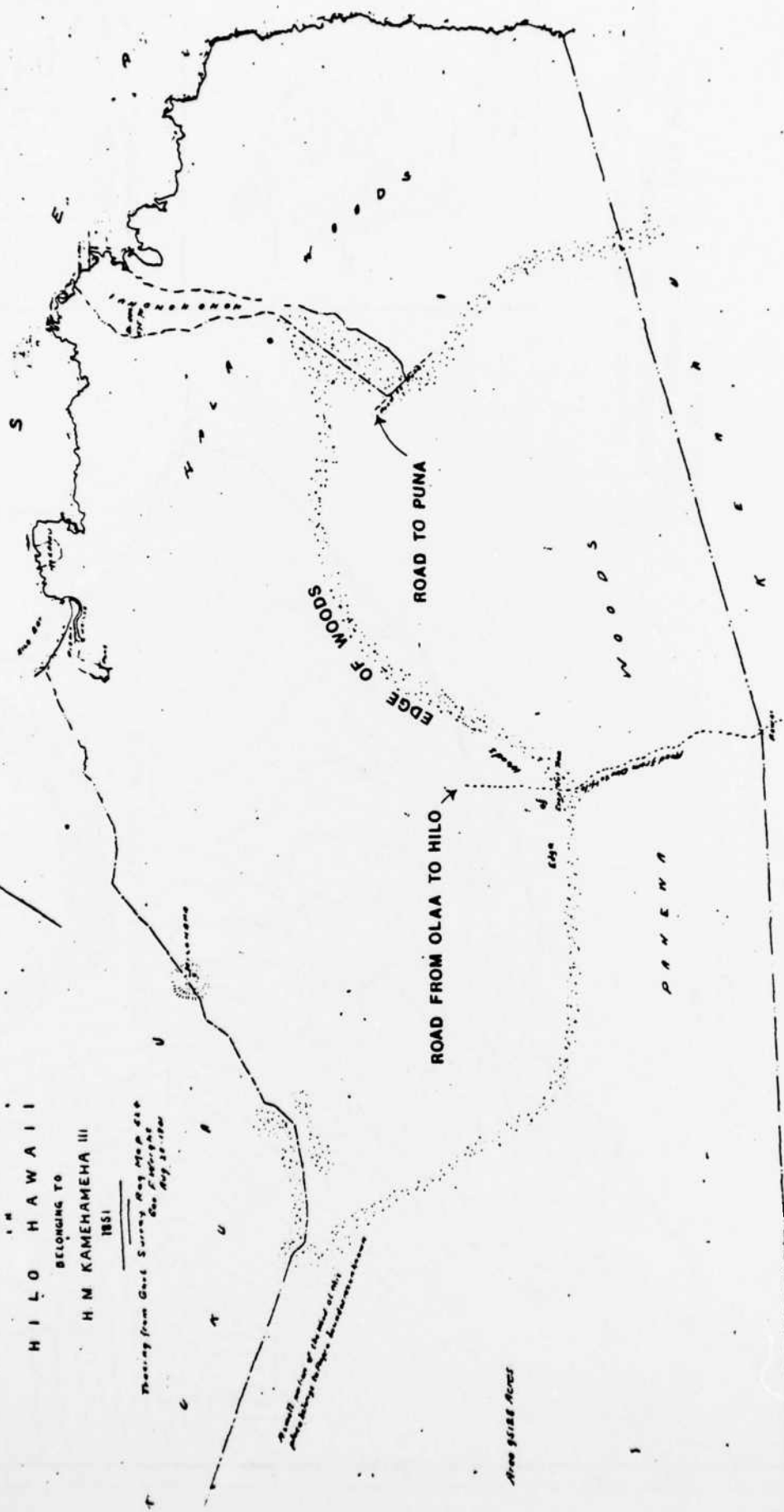


Fig. 5. MAP DATED 1851, SHOWING THE EXTENT OF THE FOREST IN WAIKEA, S HILO, THE HILO-TO-PUNA TRAIL, AND THE HILO-TO-VOLCANO TRAIL.

PLAN
WAIKEA
HILO HAWAII
BELONGING TO
H M KAMEHAMEHA III
1851

Plotted from G. S. Survey Map No. 100
Copyright
Dec. 20, 1851

TRUE NORTH



NOTE

The long line from Hilo to Kulanui here by
WESTERN SURVEY S 59° 45' W
Hilo to Kulanui S 71° 15' E
the long line along Kulanui N 76° 15' E
as the original meridian is absent from this
Map (see 1851 Survey Map No. 100, upper right corner)

SURVEY BY W. H. WEBSTER
C. L. L. 1851

(Original signature of Webster missing)

